VOL. XIII OCTOBER 1959 NO. 4

PACIFIC SCIENCE

A QUARTERLY DEVOTED TO THE BIOLOGICAL AND PHYSICAL SCIENCES OF THE PACIFIC REGION

IN THIS ISSUE: Hubbs — *Fish Faunas on Seamounts and Offshore Banks* • Bary — *Pelagic Hyperiidea from New Zealand Waters* • Moomaw, Nakamura, and Sherman — *Aluminum in Some Hawaiian Plants* • Yamashita and Waldron — *Tagging of Skipjack in Hawaiian Waters* • Smith — *The Viviparous Polychaete,* Nereis limnicola • Shiino — *A New Species of* Caligus *from California* • Winkler — *The Purple Secretion of the California Sea Hare* • Marples — *Spiders from the Kingdom of Tonga* • Kohn — *Hawaiian Species of* Conus • Index

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Initial Discoveries of Fish Faunas on Seamounts and Offshore Banks in the Eastern Pacific[1]

CARL L. HUBBS[2]

THE RECENT DISCOVERY in the Pacific Ocean of numerous submerged mountains (Hess, 1946; Menard and Dietz, 1951; Menard, 1955, and in press), including "banks" (rising to a depth of less than 100 fathoms) as well as the flat-topped "guyots" and other "seamounts" (with minimum depths greater than 100 fathoms), has posed intriguing questions regarding their faunas. Some of these questions are:

What species inhabit the individual banks and seamounts, and in what regularity and abundance?

How did these species become dispersed to and established on these structures?

What bearing may the determined constitution of these isolated faunas have on our ideas concerning past and present oceanic circulation and temperatures?

Do the banks and seamounts (as well as the islands) provide stepping stones for the transgression of narrow to broad oceanic areas, even the supposedly vast eastern Pacific barrier that separates the Indo-Pacific and American faunas (Ekman, 1953: 21, 72, 292)?

May some elements in the faunas of the deeper seamounts be relicts that have become adapted to increasing depths as the seamounts have subsided (or become flooded)? If so, the faunistic evidence may have some bearing on the historical interpretation of the seamounts.

To what degree has isolation on the banks and seamounts led to speciation?

Are either demersal or pelagic fishes (or other animals) sufficiently abundant and available on or over these isolated rises to yield profitable fisheries?

What factors, physico-chemical or biotic, are responsible for the abundance of life on and over these rises? The first thought that comes to mind is that the elevations in the bottom contour induce disturbances in the deep currents, which no doubt have greater velocities than they were long thought to have, and that such disturbances induce upwelling and the enrichment of the upper waters.

Systematic explorations of the faunas on the isolated banks and seamounts (and oceanic islands) should yield rich returns, both scientifically and commercially. As yet only fragmentary information has been accumulated. Some such fragments of data, recently acquired, concerning the fish faunas on seamounts and banks from the Gulf of Alaska to far-off Chile, are presented here.

Embassichthys bathybius (Gilbert) on Pratt Seamount

On August 22, 1951, an adult "deepsea sole" 242 mm. in standard length surprisingly was caught in a rock dredge being hauled at a depth of 510 fathoms on the side slope of Pratt Seamount in the Gulf of Alaska, at Lat. 56° 20′ N., Long. 142° 30′ W., about 210 nautical miles offshore. It was obtained by Henry W. Menard and John D. Isaacs on the research ship "Horizon," on the Northern Holiday Expedition of the Scripps Institution of Oceanography (Dredge No. 5; Collection SIO 53-187).

This record constitutes a notable northward as well as seaward extension of the range of this deep-water pleuronectid. Long known

[1] Contributions from the Scripps Institution of Oceanography. Manuscript received April 10, 1958.

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only from off southern California, recently it has been reported from off northern California (Hagerman, 1950) and from off Washington (Welander and Alverson, 1954: 42–43).

Unpublished records show that this commercially utilizable fish is not uncommon in deep waters off northern California and Washington. It is becoming of minor importance in the trawl fishery, as operations are being extended into deeper water. Its occurrence on at least one seamount suggests the possibility that the trawling grounds may eventually be extended far seaward, where depths are appropriate.

I have underway a distributional and variational study of this poorly-known flounder.

Sebastodes ruberrimus Cramer and Other Fishes on Cobb Seamount

A rockfish caught on Cobb Seamount, about 280 nautical miles off Washington and about 240 miles southwest of Vancouver Island, at Lat. 46° 44′ N., Long. 130° 47′ W., was described by Welander and Alverson (1954: 37–40, figs. 1, 2) as representing a new species, *Sebastodes bilineatus*. By examining this specimen (No. 10099, University of Washington Fish Collection) in detail on June 11, 1956, I verified the belief of Julius B. Phillips, W. I. Follett, and myself that it is a specimen of the large *S. ruberrimus*, in the striped, juvenile stage. The contrast between the dark ground color and the light stripes is unusually bold, but since color intensity varies so greatly in fishes and since all other characters observed fall within the observed range of variation of *S. ruberrimus*, it seems doubtful that the species is modified on Cobb Seamount. Slight differentiation, however, is a remote possibility. Data on the type of *S. bilineatus* will be included in a forthcoming contribution by Hubbs and Follett.

Thompson (1915: 121) observed that *S. ruberrimus* is "the most abundant of all species of the genus on the halibut banks," but in the same paper described what is now thought to be a specimen of this species as *S. babcocki*, new species.

Welander and Alverson mentioned that the type of *S. bilineatus* was one of 30 fish specimens "caught by personnel of the U. W. oceanography vessel Brown Bear in the vicinity of Cobb Seamount on August 7, 1953." It is to be hoped that complete lists of species taken on or about each seamount will be published.

Perhaps fisheries may develop on the seamounts for rockfishes (*Sebastodes* spp.), as well as for the halibut, *Hippoglossus stenolepis* Schmidt, and other flatfishes.

SHORE AND PELAGIC FISHES ON BANKS AND SEAMOUNTS OFF CENTRAL CALIFORNIA

A number of coastal and pelagic fishes of expectable species were recorded by Follett (1952) from several banks and seamounts off the central California coast, at no very great distance offshore. This is not to mean, however, that high interest and potential importance is not to be attached to such inshore rises.

TUNAS AND TUNA FORAGE FISHES FROM "STRANGER BANK" ("HURRICANE BANK")

In 1957, on an expedition from Scripps Institution of Oceanography, on the research ship "Stranger," Adrian F. Richards discovered, at Lat. 16° 52′ N., Long. 117° 30′ W., roughly 200 nautical miles southwest of Clarion Island, a shallow bank rising from oceanic depths to a depth of approximately 15 fathoms. This bank was assigned the tentative name Stranger Bank by the discoverer. Tuna fishermen of San Diego, who dub the structure "Hurricane Bank," from the heavy weather often encountered there, promptly began fishing there and in less than a year had taken from the newly found fishing ground well over 1,000 tons of yellowfin tuna, *Neothunnus macropterus* (Temminck and Schlegel), and smaller quantities of skipjack tuna, *Katsuwonus pelamis* (Linnaeus). At the time of writ-

ing it is evident that within the first full year the catch will definitely exceed 2,000 tons, with a value to the fishermen of more than one-half million dollars; and the relative proximity of the ground represents a great saving in expenses. Tuna fishermen have reported taking some rainbow runners, *Elegatis bipinnulatus* (Quoy and Gaimard), from this same bank.

During the Island Current Survey of May–June, 1958, personnel of the Inter-American Tropical Tuna Commission caught about the bank a number of young yellowfin tuna. On June 1 an adult male of the labrid *Bodianus diplotaenius* (Gill) was caught on the shoalest part of the bank (it was identified from a kodachrome). Many sharks, including some hammerheads, *Sphyrna* sp., were seen, to confirm the reports that sharks abound here. On June 5 one wahoo, *Acanthocybium solandri* Cuvier, was caught, and several mantas, presumably *Manta hamiltoni* (Newman), were seen.

Further information on other fishes that live over and about this bank comes from an initial examination of stomach contents of yellowfin tuna, collected there for the Inter-American Tropical Tuna Commission and now being analyzed by the staff of the Commission. Young to half-grown specimens of the spiny trunkfish, *Lactoria diaphana* (Bloch and Schneider), constitute a notably high proportion of the food. Some stomachs are filled with this bony creature, which elsewhere has been found to be eaten by this tuna. This trunkfish ranges very widely through tropical regions, and even, on occasions, as far northward as California. A sample (SIO 58–56) from the stomach of a tuna caught on this bank comprises 487 specimens of this trunkfish, 13 to 44 mm. in standard length. Another lot (SIO 58-57) comprises 7 specimens, of similar size. One tuna contained a large young triggerfish (SIO 58-54) of the common, wide-ranging, more or less pelagic species *Xanthichthys lineopunctatus* (Hollard); its standard length is 52 mm. Remains of flying fish of undetermined species also occur in the tuna stomachs.

A thorough study of the fish fauna of Stranger Bank is much to be desired, especially in view of the thorough analysis of the Revillagigedo fish fauna being conducted by Boyd W. Walker and associates.

For information and material on the fishes and fisheries of this bank I am indebted to Bell M. Shimada and Franklin G. Alverson of the Inter-American Tropical Tuna Commission and to Wilbert M. Chapman of the American Tunaboat Association.

Pterygotrigla picta (Günther) on a Guyot far off Chile

On January 26, 1958, a triglid fish (gurnard or sea robin) of considerable zoogeographical interest was captured incidentally in a rock dredge being hauled at a depth of 129 fathoms on a guyot rising from an extensive ridge in the southeastern Pacific. It was preserved by Robert H. Parker on the research ship "Spencer F. Baird" of Scripps Institution of Oceanography, on the I. G. Y. Downwind Expedition (Station 73; SIO 58-42). This unnamed guyot is at Lat. 25° 44′ S., Long. 85° 25′ W., which is about 800 miles off the Chilean coast, about 300 miles westerly from Isla San Felix, and nearly 600 miles northwest of Isla Juan Fernández. It is in a region where seamounts appear to be numerous, and is on a submarine ridge that seems to extend westward at least to Easter Island (Fisher, 1958: 20–25, figs. 1, 8, 9).

Although the specimen is young (54 mm. in standard length) and was badly crushed posteriorly in the rock dredge, it seems identifiable as *Pterygotrigla picta* (Günther). This species was originally very briefly described, but magnificently figured, by Günther (1880: 24–25, pl. 13, fig. A), as *Trigla picta*, on the basis of a 10.5-inch specimen collected by the "Challenger" on Isla Juan Fernández, far off the coast of Chile. The species has been reported also from New Zealand and Australia (McCulloch, 1929: 393), but not from the

American mainland. This distributional pattern seems to be related to the bottom topography within the south temperate zone of the Pacific: there is a very deep trench off the Chilean coast, but from the vicinity of islas Juan Fernández and San Felix westward numerous submarine ridges and peaks rise to various heights below and above sea level. It may be predicted that the species will be found not only on the guyot nearly 600 miles northwest of Juan Fernández, but also on other rises between the offshore islands of Chile and New Zealand. It is not known whether seamounts intervene between Juan Fernández and San Felix, and it is now doubted that the long charted intervening ridge exists.

This young specimen differs in a number of respects from the characters indicated in the original description and figure of *Trigla picta*, but these differences seem attributable to age and individual variation. The dorsal spines number VIII instead of VII, but the eighth is short and very slender (and is perhaps concealed in the type); the number of dorsal soft rays (12) agrees. The anal rays are 11, not 12, but some variation is expected. (The principal caudal rays number 6 + 5 = 11, and each pectoral has 15 rays, in the formula i, 9, ii + 3.) The nuchal spine is much longer, reaching to below the base of the third dorsal spine (probably as a function of youth), and is about as long as the humeral spine. (The pectoral fin, as in the type, reaches to about the seventh anal ray.) The preopercular spine (at the end of the cheek ridges) is double, rather than single, but the lower point is definitely the smaller, and it probably becomes obsolete in larger fish. The body is similarly marked with light-ringed blackish spots, but these spots (as expected) are fewer. On the head the spots are discernible, though faint, as though just developing. The fins, unlike those on the type, are unspotted: in the spinous dorsal the membranes are sooty outward; the second dorsal has a submarginal dark band; the pectoral is very dark, except for a light border; the other fins are almost wholly clear. In coloration the young specimen corresponds better with the figure given by Mann (1954: 309) for the "pez mariposa de Juan Fernández," which he designated *Chelidonichthys pictus*.

Trigla picta has been referred, properly I think, to the genus *Pterygotrigla* Waite (1899: 108), which was based on the Australian species *Trigla polyommata* Richardson. Although quite different in coloration, *P. picta* and *P. polyommata* seem very similar in structure.

The genus *Pterygotrigla* has been attributed to Japan (Matsubara and Hiyama, 1932: 8–14, figs. 2–5), but the Japanese species referred to the genus differ trenchantly from *P. picta* and *P. polyommata* in lacking vomerine teeth. They are also said to have a "distinct anal spine" (a hardened soft-ray?), which does not seem to be true of the Southern Hemisphere species. Though the two groups agree in many characters it seems advisable to put them in separate genera. The name *Otohime* Jordan and Starks (1907) is available for the common Japanese species *hemisticta* (the type species), and probably for *Pterygotrigla ryukyuensis* Matsubara and Hiyama.

Otohime differs further from *Pterygotrigla* in the small size of the dorsal bucklers. The distinction in the first anal ray may not be valid, for a young specimen of *Otohime hemisticta* has this ray paired, articulated, and flexible.

It seems clear from the original account that *Trigla guttata*, which was described without comparisons by Philippi (1896: 375–376) from Juan Fernández, is a synonym of *Pterygotrigla picta* (Günther)—as was assumed by McCulloch (1929: 393). But the gurnard from Islas Juan Fernández that was figured and discussed by Mann (1954: 309) as *Trigla punctata* Philippi obviously belongs in a very different species. From the figure it seems clearly referable to *Chelidonichthys*, as defined by Matsubara and Hiyama (1932: 4). It even seems probable that the specimen may be referred to *C. kumu* (Lesson and Garnot), an

important species that is accorded a range from New Zealand and Australia to Japan (see Matsubara and Hiyama, 1932: 5–7, fig. 1). Like *Pterygotrigla*, *Chelidonichthys* is unknown in Chile. Its occurrence on Juan Fernández parallels that of *Pterygotrigla picta*, and it may be predicted that *Chelidonichthys* will be found on seamounts, banks, or islands between Juan Fernández and New Zealand.

Both *Pterygotrigla* and *Chelidonichthys* belong to a distributional category that may be classified as antitropical Indo-Pacific, and contrast sharply with the American triglids (*Prionotus* and the derived *Bellator*). Comparison of a specimen of *P. picta* from Isla Juan Fernández (an adult 340 mm. in standard length collected by the Mellon Expedition in Bahia Cumberland on February 28, 1936) with specimens of *Chelidonichthys kumu* from Japan discloses many differences. The row of keeled scales along the entire dorsal base is replaced by greatly enlarged flat bucklers along the base of the spinous dorsal only. *P. picta* differs further from *C. kumu* in a feature of the lateral line, which ends simply, immediately beyond the caudal base, instead of being forked and continued as two or three lines across the caudal fin. The head is much larger, and the body is much more contracted at the base of the caudal fin, which is sharply forked rather than merely emarginate. The orbital rim is spineless, but the opercular, nuchal, and humeral spines are greatly enlarged. The nape, in advance of the greatly enlarged buckler surrounding the first dorsal spine, is scaleless rather than scaly. The teeth are almost shagreenlike; those of the lower jaw are deflected outward over the anterior edge of the lower lip. The vomerine teeth are in an oval rather than a broadly V-shaped patch. Most of these differences show in the figures reproduced by McCulloch (1922: 119, pl. 39).

NEED FOR FURTHER STUDIES

These brief notes tend to show that great scientific as well as commercial importance may be attached to a study of the faunas of the many banks and seamounts that rise toward the surface from the depths of the Pacific Ocean. Many and perhaps most of these structures seem capped and surrounded by productive water. The spectacular take of tuna on the Stranger, or Hurricane, Bank has been mentioned. Milner B. Schaefer, director of research for the Inter-American Tropical Tuna Commission, has assured me that good catches have been made about other banks and even about seamounts that nowhere closely approach the surface. Henry W. Menard of the Institute of Marine Resources, University of California, leading student of seamounts, tells me that he has obtained strong field indications, from echograms, that large objects (presumably fish or giant squid) form a halo around and far above many seamounts between California and Hawaii. It seems highly probable, as is stated in the introduction, that the submarine mountains, even those that are isolated and deep, disturb the currents sufficiently to induce extensive upwelling.

The benthic faunas of the banks and seamounts do not give promise of such commercial potential, but may prove of greater scientific interest, particularly in respect to zoogeography and speciation.

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Ecology and Distribution of Some Pelagic Hyperiidea (Crustacea, Amphipoda) from New Zealand Waters

B. M. Bary[1]

THE MARINE pelagic Amphipoda recorded from New Zealand have been discussed systematically (Stephensen, 1927; Barnard, 1930, 1932; Hurley, 1955), but few data are available on their distribution and ecology. The situation in Australia (Barnard, 1931; Dakin and Colefax, 1933, 1940) and South Africa (Stebbing, 1910; Barnard, 1916, 1925, 1940) is similar. However, in antarctic latitudes some features of the ecology of amphipods have been fairly extensively treated (Mackintosh, 1934, 1937; Hardy and Gunther, 1935).

The data presented herein are of collections made from the survey-frigate H.M.N.Z.S. "Lachlan," in southern New Zealand waters, during the summer of 1951. The hyperiids from these collections have been identified by D. E. Hurley, who generously undertook this taxonomic study (Hurley, 1955).

Fourteen species were present in the collections. Seven of these were new records for New Zealand. Five species, namely, *Parathemisto* (*Euthemisto*) *gaudichaudii* (Guer.), *P. australis* (Stebbing), *P. gracilipes* (Norman), *Cyllopus magellanicus* Dana, and *C. macropis* Bovallius, were present in sufficient numbers to permit discussing some features of their ecology, especially their relationships to the water masses in the area about southern New Zealand. The remaining nine species were of rare occurrence, although their biological and environmental associations provoke discussion.

ACKNOWLEDGMENTS

The writer gratefully acknowledges Dr. D. E. Hurley's identification of the amphipod material, useful discussions of data, and reading of typescripts and proofs.

MATERIAL AND METHODS

Details of the areas from which collections were made, the gear and the methods, are discussed elsewhere (Bary, 1956, 1959). The areas sampled extended between Wellington and Dunedin (one cruise in January, a second in March, 1951), between Dunedin and Foveaux Strait (during January through March), and between Wellington and Auckland and Campbell islands, about 400 miles south of New Zealand (one cruise, November, 1951). (See Figs. 5, 6.) Procedure and gear were standardized: tows were of 3 minutes at 1½ to 2 knots, within the surface metre of water, using a net of graded silks, 50 cm. in diameter. Of the 80 samples, those of Stations 74–85 were collected whilst the ship was at anchor overnight in a tidal stream in western Foveaux Strait (Bary, 1956). Although the temperature was taken at each of these, salinity was determined only for Station 79. Therefore, only this station is shown in the various figures. All of the rare species collected at Stations 74–85 are shown as being captured at Station 79 in Figures 2, 5*a*. Of the common species, only those captured at Station 79 are illus-

[1] New Zealand Defence Scientific Corps, c/o Navy Office, Wellington, N.Z. Now at Oceanographic Laboratory, 78 Craighall Road, Edinburgh 6, Scotland. Manuscript received May 21, 1957.

trated. All samples have been quantitatively analysed.

The method of the temperature–salinity–plankton (T–S–P) diagram (Bary, 1959) is used here to elucidate the distributions of species. Occurrences of species are plotted in the intercepts of the temperatures and salinities of the stations at which they were captured. Species are thus related to the hydrological conditions as indicated by these properties. The water-envelope (Figs. 1–4) surrounds the intercepts of all the temperatures and salinities of the surface waters in the sampled areas, but Figure 1 shows only those for plankton stations. The hydrology of the area and the relationships of these waters are illustrated and discussed by Bary (1959).

T–S–P diagrams of the five commonly occurring amphipods are shown in Figures 3 and 4. The geographical distributions of these species in relation to temperatures (Figs. 5, 6) are discussed and interpreted in the light of information derived from the T–S–P diagrams. The stations have been subdivided into several series, and each of these is as near as possible a synoptic series and a geographic unit. The geographical distribution of the subantarctic species and the coastal–subtropical species are charted for each series. Rare species are charted according to the water properties with which they are associated in the T–S–P diagram (Fig. 2). Thus, *Vibilia stebbingi* (?), at Station 210, is shown to be in water of subantarctic origin in the T–S–P diagram; therefore, the appropriate geographical chart is that which concerns other subantarctic species (Fig. 5*g*). As well, the rare species are listed in Table 1 and appreciations are made of their distributions as recorded by other investigators, and as indicated by the relationships exhibited in the T–S–P diagrams. In the charts they are shown together at Station 79 among the subtropical species.

DISTRIBUTION

Indicator groups of species were selected previously (Bary, 1959) for coastal water (one group), for water originating in the subtropical region (one group), and for the subantarctic region (two groups, a Southern Group for cold water, and a Northern Group for that cold water which has undergone a temperature increase in its progress northward). The cohesion of each of these groups in the T–S–P diagrams can only be interpreted as being due to a correlation between the distribution of the individual species composing the group and the properties of the water body which they inhabit and of which they are indicators. The area of chief concentration of each indicator group of species is shown in Figure 2 by lining-in; there are, however, no species of the Northern Group among the Amphipoda. The stippled arrows indicate the routes (within the diagram) along which oceanic species are believed to be penetrating towards coastal waters. These routes closely coincide with the direction of water movements as deduced from the corresponding T–S diagram of the surface waters (Fig. 1).

The cold-water Amphipoda are represented solely by species of the Southern Subantarctic Group (Fig. 3). Large numbers of *Parathemisto* (*Euthemisto*) *gaudichaudii* were captured; there were fewer specimens of *Cyllopus magellanicus*, and *C. macropis* was rare. Both the numbers of these oceanic species, and the frequency of their occurrences decreased in coastal waters, probably as a result of their being transferred into relatively adverse conditions. However, the greater number of the stations in coastal waters were occupied in daylight (Fig. 1) which may contribute towards the taking of fewer specimens (this feature is discussed by Bary, 1959).

The occurrences of two Coastal species, *Parathemisto gracilipes* and *P. australis*, and of the subtropical species, *Hyperoche mediterranea* Senna, are shown in Figure 4. *Hyperoche mediterranea* is restricted to a narrow range of temperature in the warmest waters (except for Station 100) whilst *P. gracilipes* and *P. australis* occur commonly over much the same salinities, but over a wider range of temperatures.

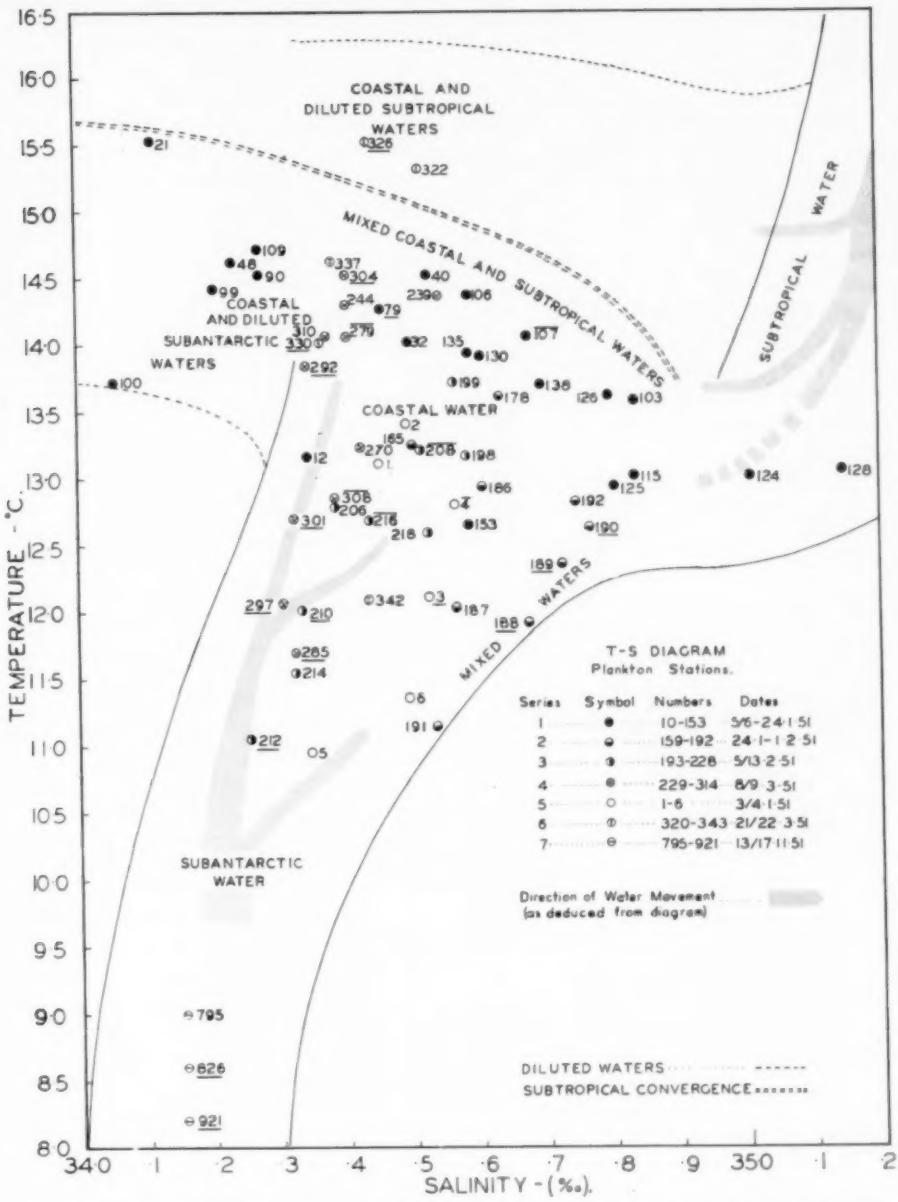


FIG. 1. Temperature–salinity (T–S) diagram of surface waters about eastern and southern South Island, New Zealand, extending southwards to Auckland and Campbell Islands. Plankton stations for which temperatures and salinities were obtained are entered. Numbers underlined (e.g., 212) represent night stations; numbers overlined represent stations between dawn and sunrise or sunset and dark. Stations without lines were occupied in daylight.

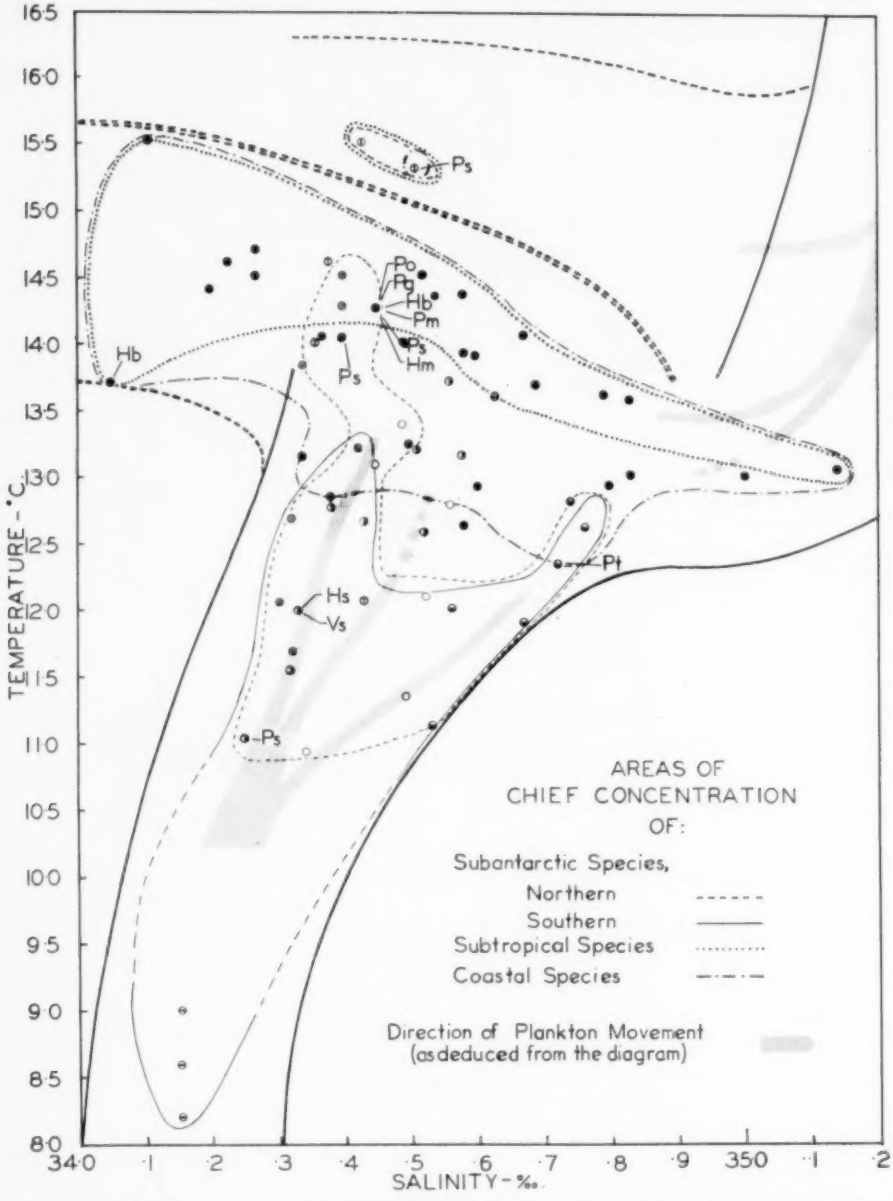


FIG. 2. Generalised T–S–P diagram showing areas of chief concentration of indicator groups of species for waters of subtropical and subantarctic origins and for coastal waters. Species captured rarely are shown by their initial letters adjacent to the station at which they were captured (see text for Station 79). *Po* = *Platyscelis ovoides*. *Pg* = *Paralycaea gracilis*. *Hb* = *Hyperia bengalensis*. *Pm* = *Primno macropa*. *Ps* = *Phronima sedentaria*. *Hm* = *Hyperoche medusarum*. *Pt* = *Parascelis typhoides* (?). *Hs* = *Hyperia spinigera*. *Vs* = *Vibilia stebbingi* (?).

The species discussed normally inhabit waters of a restricted and specified range of properties. However, the subantarctic species *Parathemisto gaudichaudii* and *Cyllopus* spp. and the Coastal species *P. australis* and *P. gracilipes* occur together at Stations 308, 292, 330, 310, 279, and again at Station 189 (Figs. 1, 2); again, the subtropical species *Hyperoche mediterranea* and the coastal species *P. australis* and *P. gracilipes* occur at Station 79. These collections of amphipods of mixed origin are present along with other species belonging to one or more of the several indicator groups of species. This is interpreted as evidence that the waters in which the species are habitually present are mixing together.

The water movements in the area have been deduced from the combined evidence of distributions of salinities, temperatures, and the zooplanktonic indicator species. They are discussed in detail elsewhere (Bary, 1959), but the isotherms of Figures 5 and 6 serve as a basis to recapitulate the main features. Briefly, there appears to be a moderately strong influence from water of subtropical origin which extends from the west into Foveaux Strait and can be traced around the coast to Dunedin and beyond. It is probable that some water of subantarctic origin, mixed with the subtropical water, also enters the Strait from the west. Water of subantarctic origin periodically penetrates in smaller or larger intrusions into the waters in the Strait and coastal areas. These several waters mix to form one of intermediate properties which is designated herein as "coastal water" (Fig. 1). It is believed probable that only water of subantarctic origin is present at Stations 826 and 921 of Series 7, and possibly also at Station 725 (Figs. 1, 6*c*). Data from stations of Series 5 and 6 (Fig. 6), together with those from a surface thermograph trace made two weeks later, on a course parallel to and seaward of the stations of Series 6, indicate the location of the subtropical convergence. It was not crossed by "Lachlan" in January when it was probably to the north of Station 1, but it was present a little northward of Station 330 in March (Series 6).

With the species of Amphipoda related to their respective waters by the T–S–P diagrams, their presence or absence at a station becomes significant in that there is an indication of the waters present. The subtropical species *Hyperoche mediterranea* is confined to that portion of Foveaux Strait likely to be most directly influenced by water of subtropical origin (Fig. 5*a*). The coastal species *Parathemisto australis* and *P. gracilipes* occur along with *H. mediterranea*, but in all series they occur over a larger area, and a wider range of temperatures. From Figure 5*a* to *d*, it is clear that neither subtropical nor coastal species penetrate into areas where the influence of water of subantarctic origin is strong, e.g., Stations 210 to 218 (Fig. 5*c*, *g*), or 285, 297 (Fig. 5*d*, *h*). On the other hand they are found, together with subantarctic species, at those stations in the mixed waters immediately northeast of Stewart Island (Fig. 5*a*, *e*) and more especially at Stations 187, 189 (Fig. 5*b*, *f*), 208 (Fig. 5*c*, *g*), 279, 292, 308, 310 (Fig. 5*d*, *h*), and again at Station 330 (Fig. 6*d*, *e*). In the T–S diagram (Fig. 1) these stations (except 187, 189) are seen to extend as a group between water of subantarctic origin and coastal water. In the T–S–P diagrams Figures 2, 3 the occurrence of the subantarctic species of plankton at all of these stations emphasises a certain affinity between them; it would seem that they are directly within the influence of water of subantarctic origin. This is confirmed by the geographic charts, which suggest that although some of the stations are located in inshore waters each, in fact, is located in the vicinity of tongues of colder water penetrating shorewards. This is especially so for Stations 279 and 292, less so for Station 208. Stations 308 and 310 appear to be in waters that are more generally mixed, but into which water of subantarctic origin appears to be intruding, particularly about Station 297 (Fig. 5*d*, *h*). Stations 187 and 189 (Fig. 5*b*, *f*) are also located near intruding

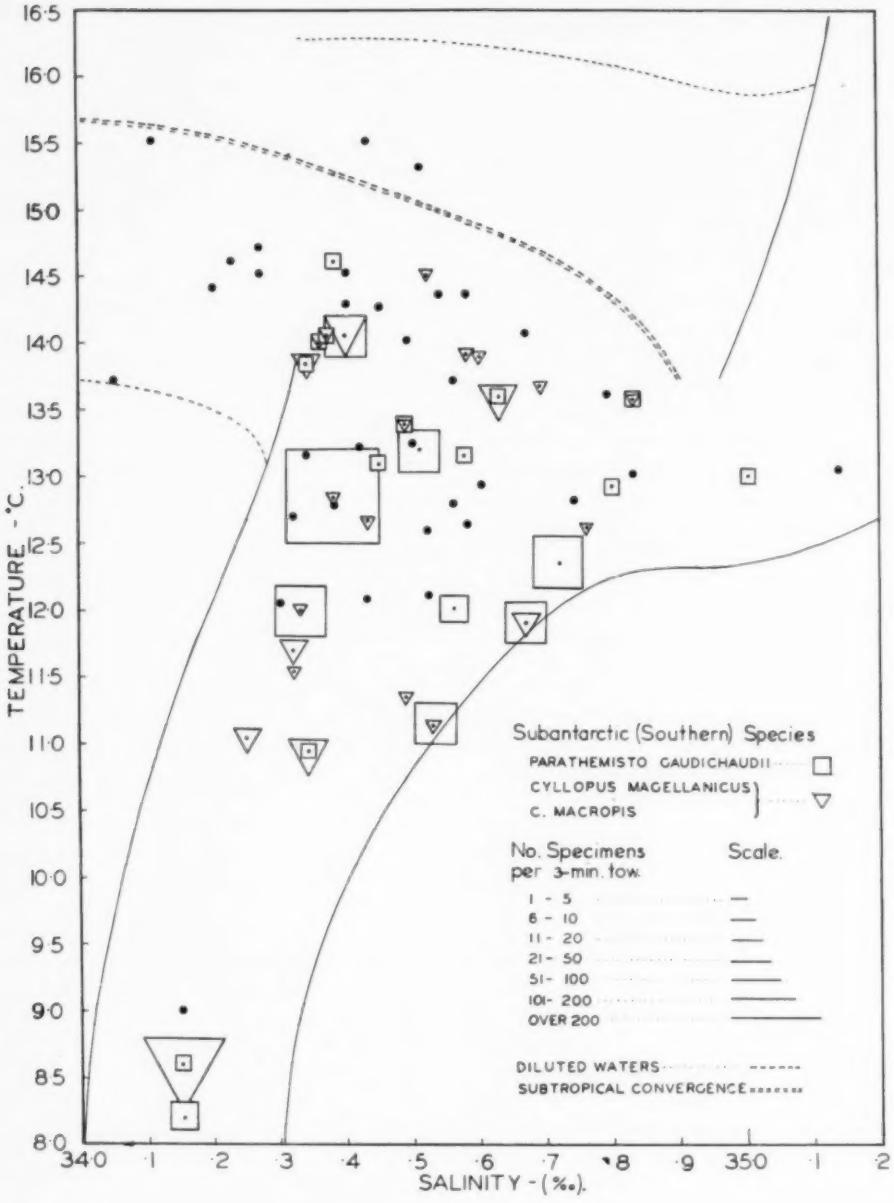


FIG. 3. Temperature–salinity–plankton (T–S–P) diagram of the species of Amphipoda associated with water of subantarctic origin.

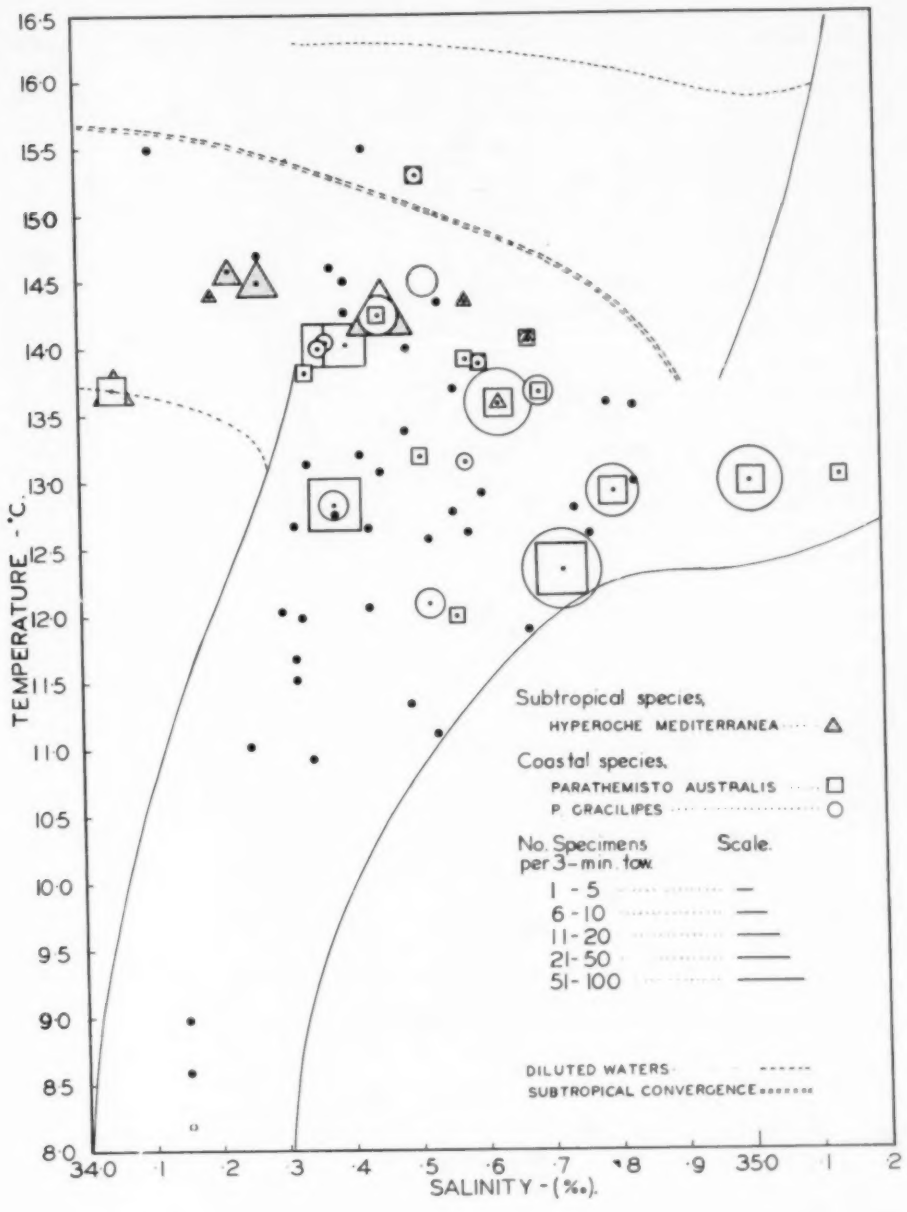


FIG. 4. T–S–P diagram of the species of Amphipoda associated with water of subtropical origin, and with coastal waters.

subantarctic water, and again the mixture of species results. At these stations there is a slightly stronger influence of coastal water than in the previous examples, as shown by higher salinities (Fig. 1). The absence of any subtropical species at 187 and 189 suggests little influence from water of this source.

The isotherms for January (Series 5, Fig. 6*a*, *b*) indicate that water of subantarctic origin extends at least to Cook Strait. One or both of the subantarctic species *Parathemisto gaudichaudii* and *Cyllopus magellanicus* are present at four of the six stations. They are absent from Stations 3 and 4. This, together with salinities which are a little higher than in neighbouring subantarctic water (Fig. 1), indicates that those stations are being influenced by coastal water, probably from south of Banks Peninsula. Although this water does not exclude subantarctic species, it supplies a reason as to why *Parathemisto gracilipes* occurs at Station 3 (and also why other species of the Coastal Group were present at both Stations 3 and 4). In Figure 6*d*, *e*, the subtropical convergence transects the series. Subantarctic species are present at Stations 337 and 330; *P. gracilipes* is also present at Station 330, and both *P. gracilipes* and *P. australis* at 322. Station 322, north of the convergence, is in mixed subtropical-coastal waters (Figs. 1, 2) and the occurrence there of a coastal species is consistent. Species from all groups are to be expected at Station 330. It is shown by the mixture of zooplankton to be situated in mixing waters in the T–S–P diagram (Fig. 2), and this is borne out by its geographical location near or within the mixing area between waters originating in the subtropical and subantarctic masses (Fig. 6*d*, *e*).

Perhaps the most important feature illustrated by Figure 6 is that the two subantarctic species, few in individuals though they are, are present only in water believed to have originated in the subantarctic. They act as indicators and demonstrate the northward extent of subantarctic water, as well as demarcate the approximate position of the subtropical convergence in March, 1951.

It perhaps should be emphasised at this point that in the southeast coastal area of New Zealand, where mixed waters of diverse origins predominate, it would be most difficult to disentangle the sources of the waters and the species from charts of distributions alone. Interpretations would be largely deductive and subjective. The T–S–P diagram demonstrates in a clear and effective manner, the source of both the waters and the species in the area. At the same time it provides a means of utilising occurrences of species to follow the trends of water movements. Thus the occurrences of species of plankton at certain localities, and of the means by which they arrived at their point of capture, can be explained with a fair degree of certainty.

Rare species are symbolised in Figures 2, 5, and 6 by their initial letters. Occurrences of one or a few species, on one or two occasions, are often insignificant in distributional studies. In the context of the T–S–P diagram (Fig. 2), however, their occurrences may assist in the interpretation of conditions; conversely, the conditions in which they occur may assist in interpreting other features concerning the species, e.g., see a later discussion of *Parathemisto* spp.

The cold-water species *Hyperia spinigera* is demonstrated as being captured in water of subantarctic origin (Station 210, Figs. 2, 5*g*)—water in which the species is normally resident. *Hyperoche medusarum* Kroyer, another cold-water species, occurs at Station 79 (Figs. 2, 5*a*). This might be regarded as a stray specimen, but the presence of small numbers of other species of the Subantarctic groups, e.g., Copepoda, suggests an intrusion of water of subantarctic origin towards this station. Two species present at Station 79 are of subtropical origin, namely *Platyscelus ovoides* (Claus) and *Paralycaea gracilis* Claus. These, and probably also *Hyperia bengalensis*, are regarded as entering, along with water of subtropical origin, into Foveaux Strait from the west. As would be expected, undoubted cos-

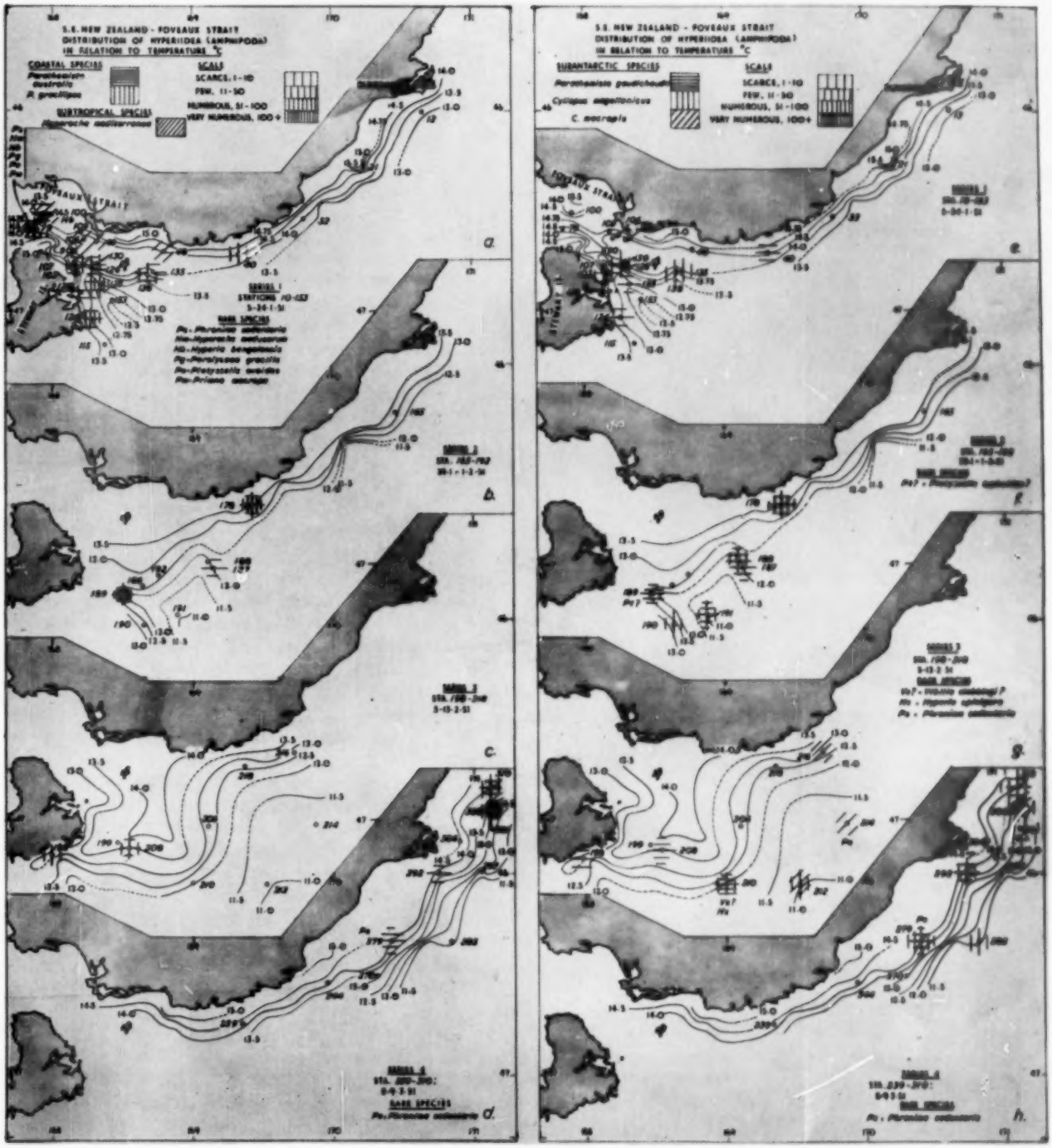


FIG. 5. Charts of distributions of Amphipoda relevant to temperature distribution about Foveaux Strait. Coastal and Subtropical species (*a–d*) are illustrated separately from Subantarctic species (*e–h*) for each series of stations. For a discussion of the rare species, see text.

mopolites may occur at stations located in a variety of waters. Thus, *Phronima sedentaria* (Forskal) is present in water of subtropical origin north of the subtropical convergence (Station 326, Figs. 2, 6*d*), in mixed water (Station 79, Fig. 5*a*), and in water predominantly of subantarctic origin (Stations 214, Fig. 5*g*), or being influenced by this water (Station 279, Fig. 5*h*). *Hyperia bengalensis* (Giles) was present in mixed or diluted coastal waters (Stations 79, 100), and *Primno macropa* Guer., another cosmopolitan species, also occurred at Station 79 (Figs. 2, 5*a*). Thus, on the whole, these species are shown to have been captured in conditions suitable for them. Conversely, their occurrences in conditions consistent with those previously recorded for them adds to the value of interpretations based on the more commonly occurring species.

Two of the New Zealand species listed in Table 1 are regarded as being doubtfully identified (Hurley, 1955). The identification of one, and possibly also of the other species, is not upheld when their relationships to the water masses, demonstrated in the T–S–P diagram, are compared with their previously recorded distributions. *Vibilia stebbingi* (?) Behn and Wolt, is present in water of subantarctic origin (Station 210, Figs. 2, 5*g*) which is out of character with the tropical-subtropical range usually ascribed to this species. *Parascelis typhoides* (?) Claus, another tropical-subtropical species was captured at Station 189 (Figs. 2, 5*f*), believed to be located in a mixture of coastal and subantarctic waters; the absence of any others of the selected Subtropical Group of species indicates little influence at this point from water of subtropical origin. Thus this occurrence of *P. typhoides* (?) may also be anomalous, suggesting again that misidentification is possible.

A comparison of the average numbers of a species captured in coastal and in offshore waters may indicate the degree to which the species penetrate from one water into the other. When numbers captured per haul over a specified range of depth are plotted against depth of water, the commoner amphipod species illustrate that this applies. (See Fig. 7; deeper water in the area of sampling is indicative of an increase of distance offshore and proximity to oceanic water.)

Both *P. gaudichaudii* and *Cyllopus magellanicus* (Fig. 8, unbroken line) show decided increases in the numbers captured from shallow (coastal) to deep water. A fair degree of tolerance to coastal waters is suggested for *P. gaudichaudii* by the almost steady increase in numbers as samples proceed offshore. On the other hand, the sudden decrease in water shallower than 50 fathoms (91.5 m.) shown by *C. magellanicus* is indicative of intolerance to conditions in the coastal water. *P. gracilipes* and *P. australis* (Fig. 7) increase in numbers to a peak at 50 fathoms (91.5 m.), and decrease in the deeper, offshore water. This suggests that neither species is tolerant of conditions in this water (see later). These facts confirm the relationships of the species to water masses already obtained from the T–S–P diagrams (Figs. 2, 3, 4).

The collections of this study were made during a period of three months. During the latter half of this a larger proportion of stations were over deeper water, either directly influenced by, or believed to be situated in water of subantarctic origin. It seemed possible, therefore, that variations in the catches of a species, relative to depth of water, might be reflected in the numbers captured at different times in the three months. So that direct comparisons might be made, the average number of specimens per haul for each month are included in the figures of changes of the catch with depth (Fig. 7 dashed line). *Cyllopus magellanicus* shows an overall decrease in numbers during January through March which is opposed to the increase with depth. Numbers of *P. gaudichaudii* on the other hand, increase with each monthly catch, although less so for March than for January and February. Even so, the number collected

TABLE 1

RARELY CAPTURED SPECIES AND THEIR PREVIOUSLY RECORDED DISTRIBUTION IN RELATION TO THAT SHOWN BY THE T–S–P DIAGRAM

SPECIES	SYMBOLS IN FIGURES	STATIONS COLLECTED	NUMBER OF SPECIMENS	DISTRIBUTION		AS FROM T–S–P	AGREEMENT
				Recorded in literature	Summary*		
1. *Vihilia stebbingi ?*	Vs	210	1	Mediterranean; 35°N.–30°S. Atlantic; E. Pacific; N.Z.	ST–T	SA	Poor (possibly misidentified)
2. *Hyperia bengalensis*	Hb	83 100	14 4	40°N.–45°S. Atlantic; Mediterranean; Arabian Sea; Cape Howe and N.S.W., Australia; Bermuda	ST–COS	Mixed ST–C–SA	Satisfactory
3. *Hyperia spinigera*	Hs	210	1	North Norway; Labrador current; W. Ireland; S. England; E. mid-Atlantic; S. Georgia; Friday Harbour; N.Z.	Arctic–Subarctic; A–SA	SA	Very good
4. *Hyperoche medusarum*	Hm	75	1	55°–77°N. Atlantic; N. Alaska; S. Georgia; at 1500–3000 m., 19°–35°S. Atlantic; N.Z.	Arctic–Subarctic	Mixed ST–C–SA	Fair
5. *Phronima sedentaria*	Ps	82 214 279 326	1 1 3 1	Mediterranean; 60°N.–36°S. Atlantic; Indo-Pacific; N.Z.	COS	82 Mixed ST–C–SA 214 } SA 279 } 326 ST	Very good
6. *Primno macropa*	Pm	74 75	1 1	Mediterranean; 30°N.–66°S. Atlantic; Indian; N. Pacific; 58°–66°S. Pacific	COS	Mixed ST–C–SA	Good
7. *Paralycaea gracilis*	Pg	83	1	Mediterranean; 53°N., 47°N., and Trop. Atlantic; 39°S., 140°E., Pacific; N.Z.	T–ST	Mixed ST–C–SA	Satisfactory
8. *Parascelis typhoides ?*	Pt	189	1	N.–S. Atlantic; Mediterranean, Red Sea	T–ST	Mixed SA–C	Poor (possibly misidentified)
9. *Platyscelis ovoides*	Po	75	3	N.–S. Atlantic; Indian Ocean and G. of Aden; Mediterannean	T–ST	Mixed ST–C–SA	Fair

* T—Tropical; ST—Subtropical; SA—Subantarctic; A—Antarctic; COS—Cosmopolitan; C—Coastal.

per haul over 100 fathoms (182.9 m.) of water increases slightly. Captures of both *P. australis* and *P. gracilipes* increase to February and decrease to March. The T–S–P diagram demonstrates, however, that the two species are resident in coastal water, and it is probable therefore that the February-March (seasonal) decrease is not more than a contributing factor to the lower number of specimens captured from the deeper water. Thus, for the most part there appears to be a considerable degree of independence between the numbers of a species captured per haul per month and the numbers captured relative to depth of water. A similar condition is also suggested by the averages of all the common amphipods (Fig. 7). The average catch increases to 100 fathoms in a similar manner to that for January and February. However, the catch from water deeper than 100 fathoms continues to increase, although at a lesser rate, while the catch for March drops sharply.

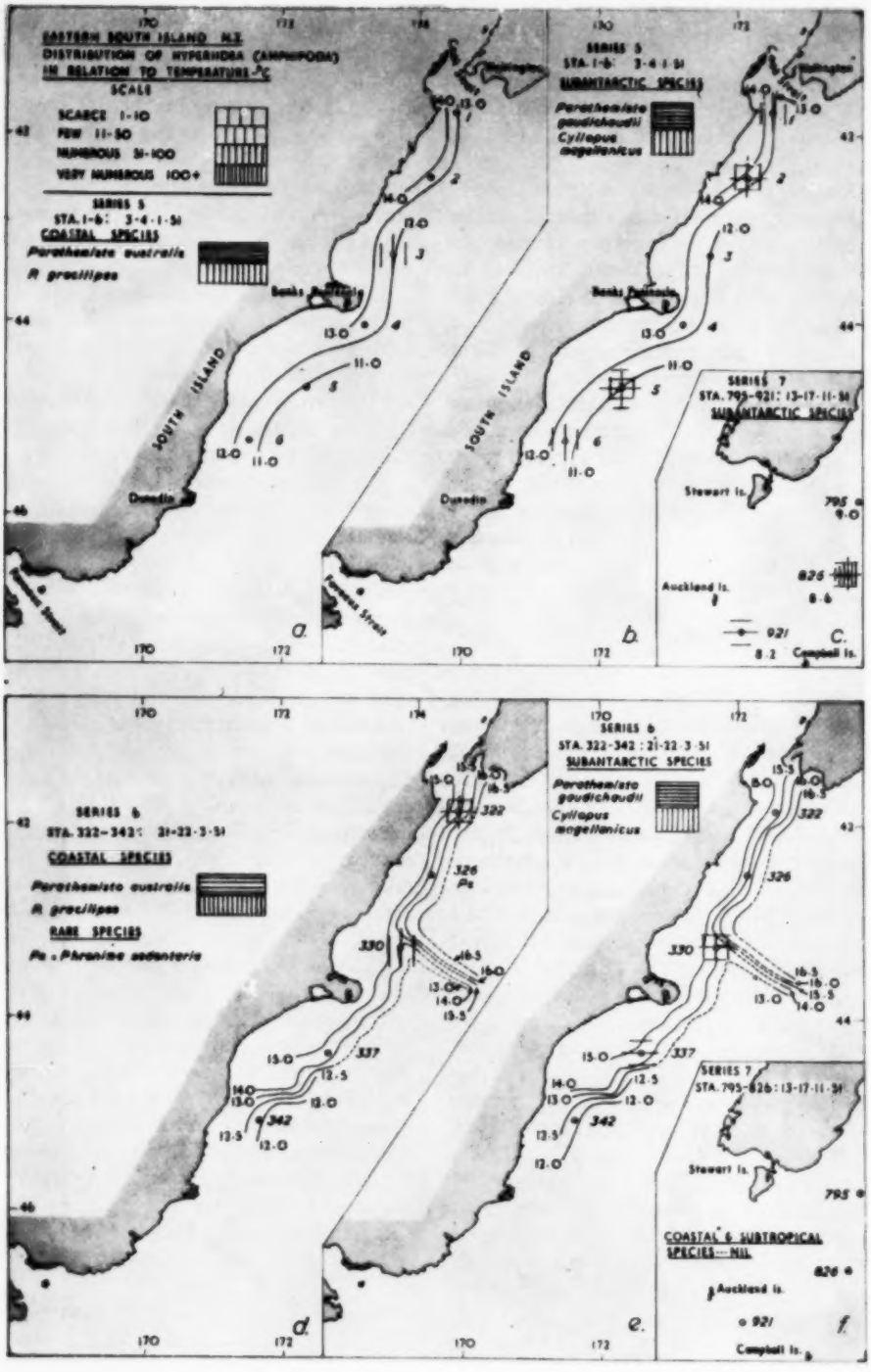
DIURNAL VARIATION

Vertical migration undoubtedly occurs among species of Amphipoda (e.g., Stephensen, 1925; Hardy and Gunther, 1935; Bousfield, 1951). However, other factors than light intensity would appear to be operative in the control of vertical distribution. Bousfield suggests quality and quantity of food, age of specimens and predation, and implies that the results of vertical migration may be modified by these. There may be vertical migration in connection with propagation as well (Stephensen). Stephensen also discusses the point that a number of species occur singly, or in groups of a few specimens. He considers that this applies to almost all deep-sea species, and also to some surface species. As well, there appears to be an inherent tendency for some species to shoal (Hardy and Gunther, 1935).

These several factors, some of which appear to be interrelated, almost inevitably would result in anomalous occurrences in terms of a normal diurnal rhythm. With species tending to appear somewhat irregularly at the surface, patchiness in their occurrences would result. Hardy and Gunther (1935) discuss such patchiness among amphipod species and the effects this has on their distribution patterns, with particular reference to the area about South Georgia.

The data on the species in the present study demonstrate that vertical migration takes place and that patchiness is frequently met. The former is reflected in diurnal variation of numbers at the surface, and the latter in the great variation in the numbers captured from hour to hour (Figs. 8, 9), or station to station, of all the common species (Figs. 5, 6). The average haul for each hour is derived from the average of one to five stations. In contrast the average number of tows per hour is low (almost three per hour), which precludes the present data from being fully representative of the patterns of diurnal variation in New Zealand waters.

However, the numbers of the five commonly captured species, and of the juveniles of *Parathemisto* spp., increased at night. *Parathemisto gaudichaudii* and juveniles of *Parathemisto* spp. exhibited pre- and post-midnight increases in numbers; although such is more or less typical of the diurnal behaviour of zooplankton (Cushing, 1951), the post-midnight rise occurs between 0100–0200 hours, which in southern New Zealand is several hours too early to be considered a predawn rise. The other species increase to a single peak during darkness either prior to (*Hyperoche mediterranea*), or subsequent to midnight (*Cyllopus magellanicus*, *Parathemisto australis*, *P. gracilipes* and *Parathemisto* juv.). A large catch of several species, made at Station 189 at 0125 hours, is responsible for the peak of numbers taken between 0100 and 0200 hours for *P. gaudichaudii*, *P. australis*, *P. gracilipes*, and *Parathemisto* juveniles. A total of four stations were occupied between 0100 and 0200 hours, but only at Station 189 were any of these species captured. This may be a result of patchiness in distribution. On the other hand, Station 189 was in mixed coastal-subantarctic


EASTERN SOUTH ISLAND N.Z.
DISTRIBUTION OF HYPERIIDEA (AMPHIPODA)
IN RELATION TO TEMPERATURE °C
SCALE
SCARCE 1-10
FEW 11-50
NUMEROUS 51-100
VERY NUMEROUS 100+
SERIES 5
STA. 1-6: 3-4-1-51
COASTAL SPECIES
Parathemisto australis
R. gracilipes
SUBANTARCTIC SPECIES
Parathemisto gaudichaudii
Cyllopus magellanicus
SERIES 7
STA. 795-921: 13-17-11-51
SUBANTARCTIC SPECIES
SERIES 6
STA. 322-342: 21-22-3-51
COASTAL SPECIES
RARE SPECIES
Ps. Phronima sedentaria
COASTAL & SUBTROPICAL SPECIES—NIL
SOUTH ISLAND
Dunedin
Stewart Is.
Auckland Is.
Campbell Is.
a.
b.
c.
d.
e.
f.

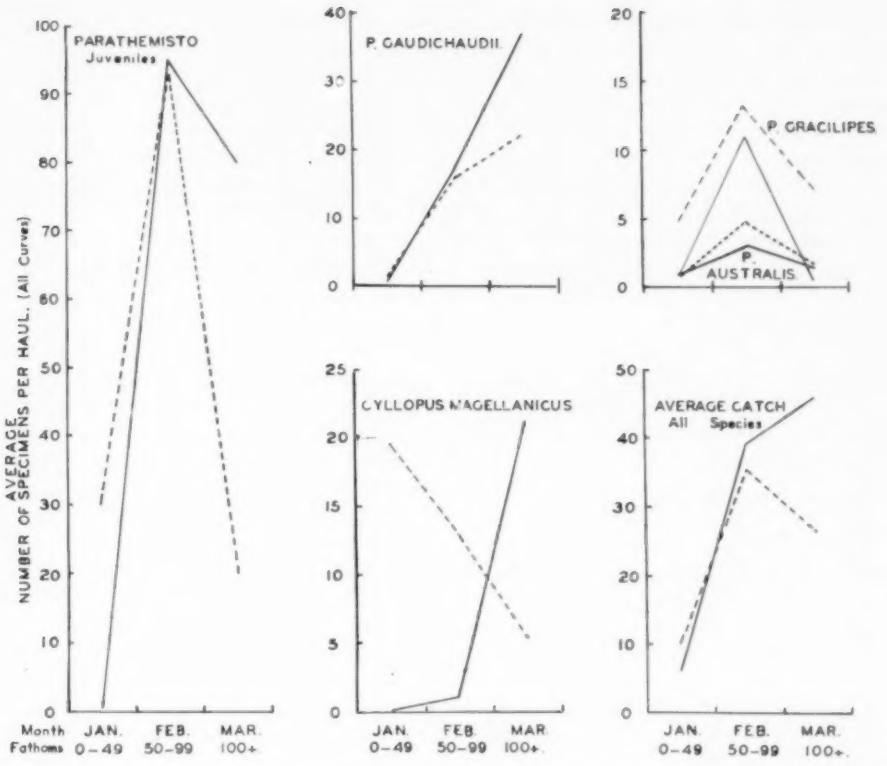


FIG. 7. The average number of the commonly occurring Amphipoda per haul per month for January, February, and March, plotted together with the average number of species per haul over each of the ranges of depth 0–49, 50–99 and 100+ fathoms (0–89.6, 91.4–181.1, and 182.9+ m.).

waters and perhaps the several species were dependent on the particular hydrological conditions. That these examples of diurnal variation are so weighted by a single haul indicates the need for a large number of samples when dealing with species exhibiting such variable distributions in time.

Several quite considerable hauls made in daylight (Figs. 8, 9) emphasise what appears to be a certain independence of controlling conditions (e.g., light intensity) in the vertical movements of the several species. Daylight hauls were scattered over a range of conditions (see Fig. 1) and thus it is unlikely that too frequent sampling in particularly favourable conditions is weighting the curves. *Parathemisto gracilipes* and *P. australis* (Fig. 8) were most consistently present in daylight, the one or the other being captured at most times. *P. gaudichaudii*, *Parathemisto* juveniles, *Cyllopus magellanicus*, and *Hyperoche mediterranea* were usually taken in very small numbers during daylight (Fig. 8). It seems probable from the 2-hour averages of all spe-

FIG. 6. Charts of distributions of Amphipoda relevant to temperature for the east coast of South Island Coastal species (*a–c*) are shown separately from Subantarctic species (*d–f*) for stations of Series 5 and 6.

cies (Fig. 9) that species may be present, in moderate numbers, up to midmorning and from midafternoon on. However, all species, except *P. gracilipes* and a few *P. australis*, were absent or rarely captured in hauls between these times.

The common species of amphipod, by their irregular, spasmodic occurrences, suggest that in New Zealand waters, as elsewhere, distribution is affected by patchiness, and that a degree of independence of known controlling factors in the vertical movements of species is probable. Interpretations of distributions of species may thus be conditioned by the presence or absence of specimens as a result of (undetected) irregularities in their vertical movements.

Parathemisto species

Hurley (1955) analyses the complex taxonomy of *P. gaudichaudii*, *P. australis*, and *P. gracilipes*. He points out (p. 161) that "although the three groups of *Parathemisto* here recorded from New Zealand can be separated quite distinctly by the pectination of the uropods, the general facies and by ecological preferences and habits, it is still possible that they do not warrant specific status. . . ." He briefly discusses the ecological data available to him from preliminary studies, and their relationships to the systematic positions of the species. As a result of the more detailed treatment possible in the present study, Hurley's general statement can now be amplified and modified.

In the preliminary studies it appeared that the habitats of *P. australis* and *P. gracilipes*, although overlapping, were separable respectively into shallow inshore waters and waters of intermediate depth. However, the T–S–P diagram (Fig. 4) shows that they occur at similar temperatures and salinities frequently at the same stations, in the warm coastal and mixed waters. In contrast, *P. gaudichaudii* inhabits colder water originating in the subantarctic, although it is able to penetrate into the inshore waters. Thus, for the area in question, there appear to be environmental preferences between *P. gaudichaudii* on the one hand and *P. gracilipes* and *P. australis* on the other, but not between *P. gracilipes* and *P. australis*, which facts are well demonstrated in the T–S–P diagrams (Figs. 3, 4).

The variations in the diurnal patterns of the three species provide further evidence toward distinguishing between *P. gaudichaudii* and *P. australis–P. gracilipes*. *P. gaudichaudii* is rarely taken at the surface during daylight, but *P. gracilipes* and *P. australis* may be common (Figs. 8, 9). There is a double peak of numbers for *P. gaudichaudii* during darkness; both *P. australis* and *P. gracilipes* occur in large numbers at one and the same time. Further, the curve of diurnal variation for *P. gracilipes* closely parallels that for *P. australis*, indicating similar reactions to changing conditions (Fig. 9). Other similarities between *P. gracilipes* and *P. australis* are apparent in their relations to depth of water, and in the increases and decreases in numbers during January through March (Fig. 7). *P. gaudichaudii* differs considerably on these two points.

Ecologically, it would appear that *Parathemisto gaudichaudii* is separable as a distinct species from *P. australis* and *P. gracilipes*. However, an ecological distinction between *P. australis* and *P. gracilipes* in the New Zealand area cannot be substantiated because of their closely parallel diurnal behaviour and similar distribution. These points are probably not of sufficient moment to make *P. gracilipes* and *P. australis* conspecific, especially as Hurley states the two forms are readily separable by their general facies. Their previous distributional records, too, indicate that the former is an oceanic, and the latter a coastal species. Although such markedly different distributions should be reflected in their relationships to water masses in T–S–P diagram, this is not so. Thus the ecology of *P. gracilipes* and *P. australis* does little to assist in clarifying their systematic positions. On balance, it seems, however, that some taxo-

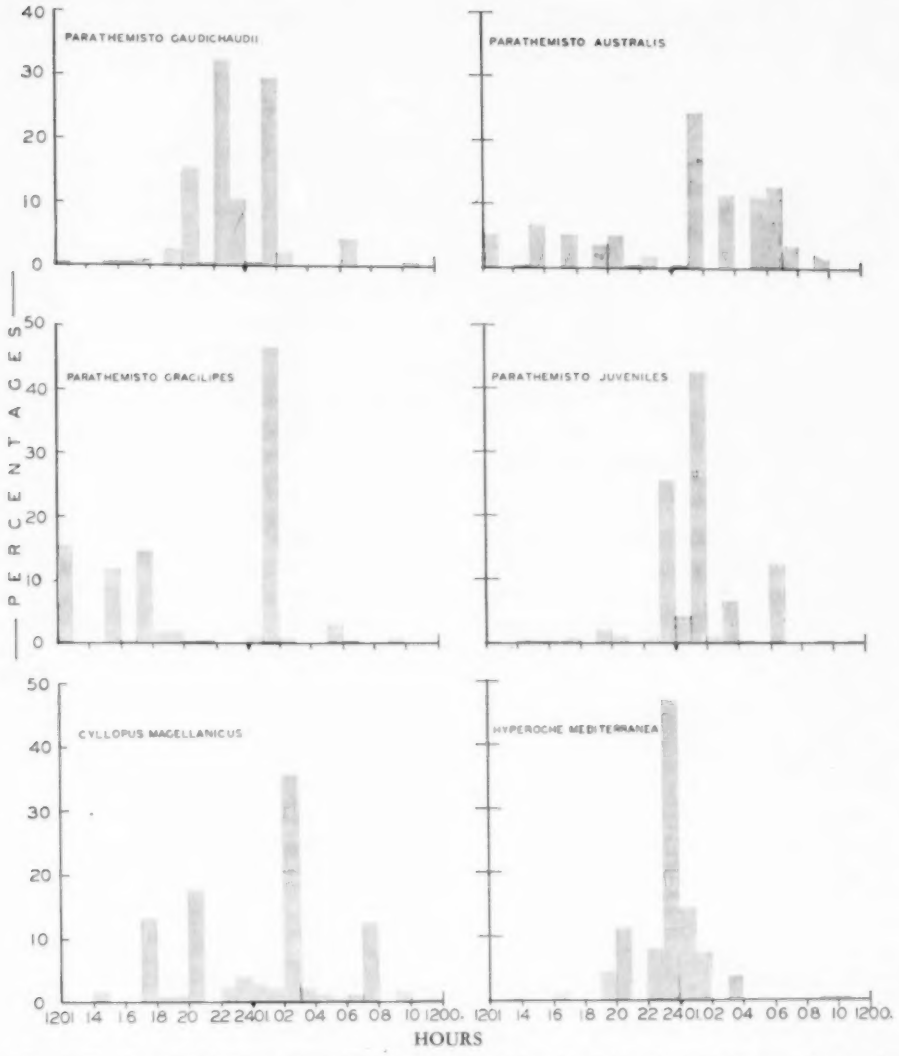


FIG. 8. The diurnal variation at the surface as shown by the hourly catches of commonly occurring species expressed as a percentage of the total catch of the species.

nomic distinction between them is desirable, but preferably at an infraspecific level.

AMPHIPODS IN THE ECONOMY OF THE AREA

An assessment of the position of species of Amphipoda in the productive economy of southern New Zealand waters was not aimed at, although the common species would seem to be important. Species are frequently captured and may occur in large numbers, even in the 3-minute tow, e.g., 729 *P. gaudichaudii* collected from 22 stations; 408 *P. gracilipes*

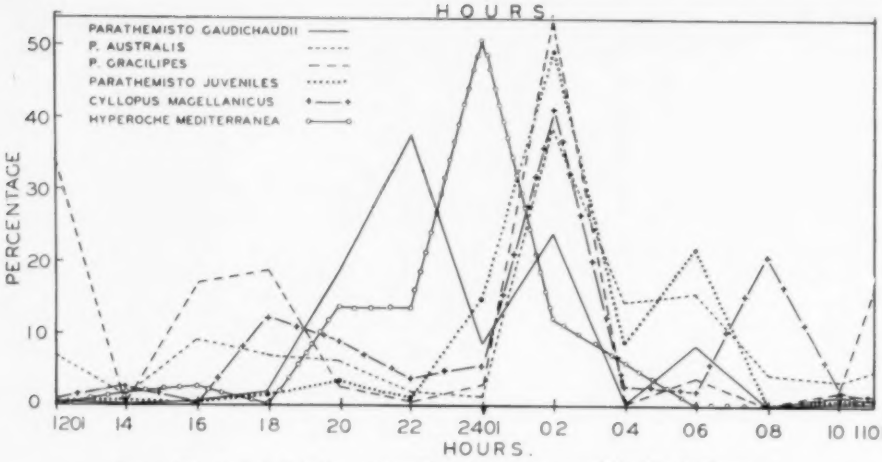


FIG. 9. The diurnal variation as shown by 2-hour averages of the data in Figure 8.

from 18 stations; 3,500 *Parathemisto* juveniles from 32 stations. The numbers of juveniles captured decrease rapidly between February and March (Fig. 7) but, even so, they were present in fairly high numbers throughout the summer. They ranged in size between specimens just released from the brood pouch to about 6.5 mm. long (at which length they usually can be assigned to sex and species), and because of their numbers are probably important in food cycles.

Barnard (1930) noted an increase in the sizes of the adults of Amphipoda at higher latitudes. In the present material, specimens of *Cyllopus magellanicus*, captured in the warmed waters (12–13°C.) of subantarctic origin off the New Zealand coast, averaged 7 to 8 mm. long and only occasionally exceeded 9 mm.; those from Station 826 (Fig. 6), in colder water (8.6°C.), averaged 9 to 10 mm. and were often 11 mm. and longer. If numbers of a species were maintained in the colder waters, such an increase in size would be reflected in an increased bulk of material available as food. Thus the size-increase in southern waters may well be related to production, the more so if it is a widespread phenomenon among those dominant species of the zooplankton.

Except for juvenile stages, the numbers of the species of amphipods captured do not reach those of some euphausiids or copepods in the area, but their large size and frequent occurrence in both oceanic and coastal waters (together with the fact that oceanic species may extend into coastal waters), suggest that species are important in productivity throughout the area. This is in part borne out by the quantities of these and other species of amphipod which are often present in the stomach contents of birds (e.g., Dawbin, 1954), and by personal observations of *Puffinus griseus* (flocks of which reach many thousands of birds) and of fish stomachs.

DISCUSSION AND SUMMARY

Of the 14 species of hyperiid Amphipoda collected by the "Lachlan" between Wellington and Auckland-Campbell islands, five are sufficiently common to be of value in studies of distribution. The occurrences of these and the remaining nine species are of interest when considered in relation to the water properties from which they were taken. In general, a strong affinity to the subantarctic, and to a lesser extent the antarctic faunas, is indicated in the frequent occurrences of species typical of southern waters, viz., *Parathe-*

misto gaudichaudii and *Cyllopus magellanicus* (and also *C. macropis*). Two species, *Hyperia spinigera* and *Hyperoche medusarum*, were rarely captured, but may be considered as inhabitants of cold waters. In the New Zealand area the first occurred in water of subantarctic origin, the second in mixed water, probably being influenced by subantarctic water. The influence of subtropical water is apparent in the moderate numbers of *Hyperoche mediterranea*, a warm-water species captured in western Foveaux Strait. Additional evidence of this influence accrues from the rare occurrences of other warm-water species, *Platyscelis ovoides*, *Paralycaea gracilis*, and possibly also *Hyperia bengalensis*. The cosmopolitan species *Phronima sedentaria* and *Primno macropa* were in low numbers, but were present in mixed subtropical-coastal waters and also in water of subantarctic origin.

There is reasonably close agreement between the distributions of species relative to water properties in the area, as shown by the T–S–P diagrams, and their distributions as recorded previously. It is rare in these earlier accounts for temperatures and/or salinities to be included, the relationships of which are important to the interpretation of species' distributions; nor are the interrelationships of species necessarily discussed. Data relevant to these features are necessary in discussion of vertical distribution where waters of diverse origins may be more or less stratified, and in horizontal distribution where waters of different properties may be mixing. It appears of small value to record the presence of species without also obtaining hydrological data by means of which ecological and distributional relationships may be assessed. With these data collected, the T–S–P diagram offers a means of precisely summarising it and, at the same time, demonstrating some of these relationships. The diagrams also emphasise the need to include, at least, data on temperatures and salinities in any discussion of distribution.

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Aluminum in Some Hawaiian Plants[1]

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and G. Donald Sherman[2]

The recent interest in Hawaiian gibbsitic soils (Sherman, 1957; Tamura, Jackson, and Sherman, 1955) as a potential commercial source of aluminum has stimulated concurrent interest in the plants of these latosols.

The major and closely related questions that arise concern (1) the role of plant species or plant communities as indicators of aluminum, (2) the ecological significance of plant accumulators of aluminum, and (3) the role of aluminum in plant metabolism and its relation to plant tolerance and toxicity. It is the purpose of this paper to discuss data on a selection of Hawaiian plants with emphasis on the latter two questions. The floristics and ecology of study sites on gibbsitic soils will be considered later.

Review of Literature

Much of the early development of information concerning aluminum in plants was stimulated by the interest in plant materials as mordants for the dye industry. Aluminum is one of the most abundant elements in the soil and is almost universally present in plants but varies widely in amount. Robinson and Edington (1945) define an "accumulator" plant as one which takes up "the particular element in quantities very far above, sometimes many thousands of times above, the average for 'normal' plants." If the mean Al^{+++} content of herbaceous vegetation is taken to be about 0.02 per cent of the dry matter (Hutchinson, 1943) or 200 p.p.m., the criterion of 1000 p.p.m. or 0.1 per cent used by Webb (1954) in a semiquantitative test would seem to be adequate to qualify a plant as an aluminum accumulator. Many workers have reported aluminum contents of non-accumulator plants, corn for example (Meyer and Anderson, 1952), that equal this level. Several studies have attested to the variability of aluminum content within individual plants, usually with higher concentrations in roots and stems than in leaves and variability within a species when grown on different substrates (Webb, 1954). The extensive work of Webb and of Chenery (1948, 1948*a*, 1951) on local and world-wide floras has resulted in compilation of lists of aluminum accumulators. The highest content of aluminum found in plant tissue is reported for *Symplocos spicata* (Webb, 1954), 7.1 per cent, and for a *Carpinus* species, 8.5 per cent (Howard and Proctor, 1957). Massive deposits of almost pure aluminum succinate have been found in the heartwood cavity of *Cardwellia sublimis* (Webb, 1953) and *Orites excelsa*. Costin (1954) stated *Poa caespitosa* to have an aluminum content of 7.8–10.4 per cent and showed that it produced a material richer in sesquioxides than the parent rock from which the soils of the region were derived.

Chenery (1951) challenges the emphasis of some Russian workers on the role of aluminum accumulators in podzolization and offers other explanation for the observed soil aluminum distribution. Howard and Proctor (1957) studied the floristics of the bauxitic soils of Jamaica and found few of the families of accumulator species in Jamaica and fewer still on the bauxitic soils. They used neither tissue nor soil analyses but reported no species they could call indicators of aluminum and, on the contrary, concluded that factors other than the aluminum content of the soil controlled the success or failure of plants on Jamaican bauxite.

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Aluminum is thought to function in plant maturation and seed setting (Hutchinson, 1943) and in water uptake. The work relating aluminum to the blue pigments in plants (Chenery, 1948), especially in *Hydrangea*, is well known. The element has been thought to exercise a strong influence in plant competition in pastures (Shorland, 1934). Aluminum accumulation is thought to be a primitive phytogenetic character in plants (Webb, 1954) because it is generally confined to the Archichlamydeae and the primitive sections of Metachlamydeae. High aluminum concentrations are rarely found in monocotyledons (Chenery, 1949) and Webb records no positive Gramineae of 16 species tested. In the pteridophytes, accumulators are again confined to more primitive families and *Lycopodium* has been extensively studied to relate aluminum content and alkaloid molecular weight. Hutchinson (1943) considered the evidence in *Lycopodium* to suggest "that the capacity to accumulate the element has been developed more than once in the genus."

Although some workers have reported a requirement for the element in trace amounts (Hutchinson, 1945) by some plants, and stimulation from aluminum, especially of the ferns (Yoshii, 1939), it is not usually considered to be one of the essential nutrients. The more frequently reported condition is that of aluminum toxicity (Gilbert and Pember, 1935; McLean and Gilbert, 1926; Rees and Sidrak, 1956). This effect is usually related to soils below pH 5.5 (Chenery, 1951; Nagata, 1954) and is frequently correlated with high concentrations of manganese and free oxides or soluble aluminum compounds in leached podzolic and latosolic soils (Ellis and Truog, 1955; Perkins *et al.*, 1955). Magistad (1925) reported toxicity on an alkaline soil from a soluble aluminate and demonstrated the insolubility of aluminum in circumneutral soils, nutrient solutions, and water.

The free hydrated oxides of iron and aluminum have been shown to be more effective in fixing phosphorus added to Hawaiian soils than are the crystal lattice clays of either the 2:1 or 1:1 types (Chu and Sherman, 1952). Free aluminum oxides do occur in montmorillonite clays (Ellis and Truog, 1955) however, and do account for most of the phosphorus fixation in soils of this type. Nagata (1954) has shown this effect to be more pronounced on calcicolous plants and Saeki and Okamoto (1954), studying the pure aluminum-phosphorus system, showed complete fixation to occur only when the P/Al ratio was less than unity and that iron and aluminum systems showed an almost identical trend. Perkins *et al.* (1955) attributed phosphate-fixing soluble aluminum to decomposition products of clay minerals.

Wright and Donahue (1953) definitely show aluminum to interfere with the phosphorus metabolism by precipitation on the root surfaces although Wallihan (1948) concludes that aluminum does not interfere with the activity of phosphorus in the tops of ladino clover plants. Rees and Sidrak (1956) found aluminum induced phosphorus deficiency in barley but not in spinach or *Atriplex*.

Hou and Merkle (1950) reported little correlation between pH and aluminum content even though accumulator plants are usually calcifugous and have a greater content of either aluminum or manganese than "acid-indifferent" plants.

METHODS

Collection Procedure

Samples of a selection of plants from three of the Hawaiian Islands were collected during the winter of 1957–58 (October–March). The principal areas of collection were those soil series currently under investigation as potential sources of alumina (gibbsite). About 500 grams of fresh plant material were collected of mature leaf, frond, or shoot unless otherwise specified. Special attention was given to some of the species known to be accumulators of aluminum and in many cases the same species were collected in areas of nonaluminous soils.

The species sampled were about equally divided among Pteridophyta, Dicotyledoneae, and Gramineae, the emphasis on grasses resulting from the present use of these areas mainly for grazing. The plants were identified by J. C. Moomaw and E. Y. Hosaka.

Analytical Procedure

Chenery's colorimetric analysis of aluminum using thioglycollic acid as inhibitor for iron (Chenery, 1948*b*) was followed with a few modifications.

The plant samples were prepared for analysis of aluminum according to the method described by Piper (1944). Two grams of oven-dried plant material were dry-ashed in a Vycor crucible. The ash was put into solution with dilute hydrochloric acid and the silica was separated and destroyed with hydrofluoric acid.

A suitable aliquot of the plant digest was first pipetted into a 100 ml. beaker and diluted to about a 20 ml. volume. To prevent the interference of Fe^{+++}, 2 ml. of 1:100 thioglycollic acid was added to the diluted solution to reduce the Fe^{+++} to Fe^{++}. Next, 10 ml. of the aluminon mixed reagent was added. The pH of this entire mixture was adjusted to 4.2 with NH_4OH using the Beckman pH meter. Although Chenery's mixed reagent is buffered at pH 4.0, the extreme acidity of the plant digest overcomes the buffering capacity and makes this pH adjustment necessary. The intensity of the color of the aluminum lake is highly sensitive to pH changes; therefore, in order to have reproducible results, it was necessary to have the pH of the plant sample and the standards equal.

The adjusted solution was transferred to 50 ml. volumetric flasks and heated in a boiling water bath for 12.5 minutes. The flasks were removed and allowed to stand for 10 minutes, then they were immersed in a cold water bath to be cooled to room temperature. The cooled solution was diluted to mark and mixed. The transmittancy of the solution was read on the Klett-Summerson photoelectric colorimeter using a green filter.

RESULTS AND DISCUSSION

Of the 45 determinations reported in Table 1, 18 exceed the Chenery criterion of 1000 p.p.m., thus designating 13 of the 23 species as aluminum accumulators for one or more of the determinations. Three of the 13 are well known from the literature as accumulators: *Lycodium cernuum*, the club moss or wawae'iole; the staghorn fern, *Gleichenia linearis;* and *Melastoma malabathricum*. The magnitude of the aluminum content of *Lycopodium* species is in good agreement with the 0.71 per cent found in the extensive review of Hutchinson (1943) and others. Staghorn is considered by some to be a fair indicator plant for bauxitic soils and was given special attention in being collected from seven different stations. It shows a high aluminum content from all collections falling in the relatively narrow range of from 3500 to 6300 p.p.m. High aluminum contents from nonaluminous soil areas, such as the Naalehu pahoehoe lava and the Honokaa soil (Table 2), are taken as evidence that it may be an obligate accumulator. *Melastoma* shows a very high content of aluminum, especially in the older tissue; this is a condition frequently mentioned in the literature, although Webb indicates some variability in *M. polyanthum* in New Zealand.

The highest aluminum content was found in *Polypodium phymatodes* on the Haiku series site considered most highly gibbsitic. Webb (1945) found all species in *Polypodium* examined by him to be negative but it is not known whether *P. phymatodes* was one of these. *Stenoloma chinensis*, another of the Polypodiaceae, shows evidence of a strong accumulation tendency, although it becomes a rather low-level accumulator on the Kukaiau soil series.

Pityrogramma and *Nephrolepis* (Boston fern), also in the Polypodiaceae, have a mixed record and indicate a facultative accumulation tendency. Two tree ferns, *Sadleria cyatheoides*

TABLE 1

ALUMINUM (Al^{+++}) CONTENT OF SOME HAWAIIAN PLANT MATERIALS IN PARTS PER MILLION OF DRY MATTER

(All determinations are means of duplicates unless agreement was not closer than 10 per cent, when additional samples were run.)

	MAUI				KAUAI		HAWAII			
Soil Series	Haiku				Kapaa		Pahoehoe lava	Kukaiau	Honokaa	Lithosol
SPECIES	Camp Maui	Halehaku	Haiku	Haiku (beyond gulch)	Bauxite Reclamation Site	Wailua Game Reserve	Naalehu	Hamakua	Kukaiau	Keaau
Pteridophyta										
Cibotium chamissoi									210	
Gleichenia linearis		3490	5670	6300		5875	4650	5725	4825	
Lycopodium cernuum			8950							
Nephrolepis exaltata		350	6660			3850		570		
Pityrogramma calomelanos		204	3525	150						
Polypodium phymatoides				16,000						
Sadleria cyatheodes					210					
Stenoloma chinensis		1795	6100	1550	1200			1200		
Spermatophyta										
Monocotyledons—Gramineae										
Digitaria decumbens	64		780							
Paspalum conjugatum									115	
Paspalum orbiculare			1400		2525 (young shoots)	5970				
Setaria geniculata			1540							
Sporobolus capensis			5475							
Monocotyledons—Orchidaceae										
Spathoglottis plicata			3550							
Dicotyledons										
Cassia leschanaultiana			660			1600				
Macadamia ternifolia (var. 246)										59
Macadamia ternifolia (var. 333)										60
Melastoma malabathricum					5500 (terminal shoots)	10,300				
Metrosideros collina subsp. *polymorpha*					70 (terminal shoots)					
Psidium guajava			247			250			250	
Rhodomyrtus tomentosa									110	
Solanum nodiflorum		3850								
Stachytarpheta cayannensis			680							
Styphelia tameiameiae				880						

in the Polypodiaceae and *Cibotium chamissoi*, contained very low levels of aluminum where they were encountered.

Among the monocotyledons, the common, naturalized, wild orchid, *Spathoglottis plicata* was found to have a sufficiently high aluminum content in the leaves (3550 p.p.m.) to be classed as an accumulator but the single determination is considered insufficient for a firm decision. This is the first known positive report for orchids.

The three positive finds for the grasses are thought to be especially interesting because of their involvement in the phosphorus metabolism of herbivores and because of negative reports for 16 species by Webb (1945), and for the family in general by Hutchinson (1943). Costin (1954) is the only known source of a positive graminaceous determination. All three of the species of grasses with high aluminum are common in the native pastures on the acid soils of the high rainfall areas in Hawaii. Yellow foxtail (*Setaria geniculata*) was relatively low (1540 p.p.m.) for a single determination, but rattail grass (*Sporobolus capensis*) contained more than 5000 p.p.m. in the Haiku area. Rice grass (*Paspalum orbiculare*) qualified as an accumulator in all three of the collection locations and shows a tendency toward increased aluminum content with age as well as a wide range (1400–5970 p.p.m.). It should be pointed out that the accumulation of aluminum in a forage grass may account in part for the observed phosphate deficiency symptoms of cattle grazing in these areas since it has been shown (Hutchinson, 1943) that ingestion of aluminum lowers phosphorus levels in blood, bone, and urine of several other animals. Hilo grass (*Paspalum conjugatum*) and fountain grass (*Pennisetum ruppelii*) were low in aluminum where they were collected and the introduced pangola grass (*Digitaria decumbens*) was very low.

The dicotyledons of interest, other than *Melastoma*, are the dark-blue-fruited nightshade, or popolo, *Solanum nodiflorum*, which was high (3850 p.p.m.) in aluminum, and Japanese tea (*Cassia leschenaultiana*), which was positive on Maui but not on Kauai. The widespread and remarkably adaptable ohia lehua (*Metrosideros collina* subsp. *polymorpha*) was very low, as was the closely related Macadamia nut (a member of the Proteaceae). These two plants and pangola grass show such low levels of aluminum that a metabolic device for excluding aluminum seems probable. *Rhodomyrtus* contains a slightly low level but guava (*Psidium guajava*) maintains a consistently "average" value even on soils varying widely in aluminum content (Table 2). Although a more intensive sampling program may reveal more members of these categories as well as more samples of an intermediate nature, it seems reasonable to classify the plants sampled—all calcifugous species growing on soils of low pH, and highly leached root zones—into the following categories:

1. Plants that exclude aluminum to some degree
2. Plants that take up aluminum
   Facultative accumulators
   Obligate accumulators
3. Plants indifferent to aluminum in the substrate

Supporting physiological evidence is needed

TABLE 2
ALUMINUM CONTENT, DOMINANT SOIL MINERAL, AND CLASSIFICATION OF HAWAIIAN SOILS FROM WHICH PLANT SAMPLES WERE TAKEN

SOIL SERIES	GREAT SOIL GROUP	DOMINANT SOIL MINERAL	ALUMINUM CONTENT (% Al_2O_3)
Haiku	Humic ferruginous latosol	Free oxides	25–40
Kapaa	Aluminous ferruginous latosol	Free oxides	40–60
Kukaiau	Humic latosol	Free oxides, amorphous minerals	20–35
Honokaa	Hydrol humic latosol	Free oxides, amorphous minerals	15–30

but it can be inferred from reports in the literature that the exclusion or accumulation of aluminum is closely related to the phosphorus metabolism of a particular species, and that presumably the phosphorus balance in the plant can be maintained either by restricting the intake of aluminum which precipitates phosphorus, or by precipitating aluminum in the leaf or other tissue in a form that will not interfere with the phosphorus metabolism.

SUMMARY

The aluminum content of selected Hawaiian plants was determined using the "aluminon" method. The plants were obtained largely from highly leached latosol soils of low pH known to have a high aluminum content. Aluminum content of some species classed as accumulators of aluminum agree closely with literature sources. High levels of aluminum are reported for the first time from some common grasses (*Sporobolus capensis* and *Paspalum orbiculare*) and from an orchid (*Spathoglottis plicata*). Thirteen of 23 species qualified as accumulators (>1000 p.p.m.) and others had unusually low aluminum levels. A classification scheme to include "aluminum-excluders" is proposed and the relationship to phosphorus metabolism is discussed, including the possible influence of plant aluminum on phosphorus levels of grazing herbivores.

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Tagging of Skipjack in Hawaiian Waters

DANIEL T. YAMASHITA and KENNETH D. WALDRON[1]

THE FISHING of the Hawaiian skipjack (*Katsuwonus pelamis*) though relatively small if compared with the major fisheries of the United States, is the most important commercial fishery in the Hawaiian Islands and the only American fishery exploiting mid-ocean stocks of skipjack. Annual landings average about 11,000,000 pounds with a value to the fishermen of about one and a half million dollars.

The Pacific Oceanic Fishery Investigations (POFI), of the U. S. Fish and Wildlife Service, is engaged in a skipjack tagging program which, it is hoped, will provide information that will increase the effectiveness of the local fishery. Tagging offers a direct means of increasing our knowledge of the growth rates, general migrations, and inter-island movement of the fish. In this report we will describe the type of tags used and the results of our initial studies during the years 1954 to 1956.

A major difficulty in early tuna tagging investigations (Rounsefell and Kask, 1945; Wilson, 1953) was the lack of a suitable tag. Alverson and Chenoweth (1951) contributed to the development of a better tag by their water tunnel experiment to determine the effect of flowing water on various tags attached to frozen albacore (*Germo alalunga*). Following this work, the California Department of Fish and Game developed a tubular plastic tag (Wilson, 1953) and used it extensively for tagging albacore, yellowfin (*Neothunnus macropterus*), and skipjack tuna (Ganssle and Clemens, 1953; Blunt, 1954); this tag is often called the type G or spaghetti tag.

Prior to announcement of the successful California tag, POFI experimented with several other types, both at sea and in ponds. These tests involved internal tags and external tags of the hook and streamer type. Experiments conducted in 1950 and 1952 were either inconclusive or unpromising, so the California tag (Fig. 1) was adopted for use in Hawaiian waters from 1954 to 1956.

APPLICATION OF THE TAGS

The type G tag was applied in the manner described by Wilson (1953), with certain modifications. Skipjack were caught by live-bait fishing methods as described by June (1951), with 3 or 4 men in the racks. A skipjack was hooked, swung up, caught by the fisherman, passed to a man designated as "holder," the tag was attached, and the fish was returned to the water. With an experienced crew a skipjack could be tagged and returned to the water in about 20 seconds.

Because it is difficult to handle skipjack without injuring them, various methods including canvas cradles, padded boxes, and electronarcosis were used in attempts to calm the fish. None of these was successful. Since it was deemed necessary to return skipjack to the water as rapidly as possible and since our efforts to quiet the fish were unsuccessful, no attempt was made to measure individual fish. Instead an estimate of the size of skipjack tagged was obtained by measuring fish which were caught and not tagged. Brock (1954) has shown that skipjack school by size, so it was believed that a reliable estimate of the size of tagged fish was obtained in this manner.

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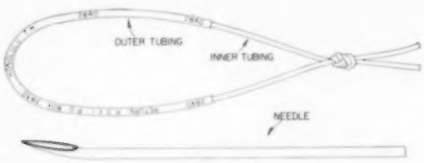

FIG. 1. California type G tag and tagging needle. Legend is on inner tubing only; serial numbers on inner and outer tubing.

Most of the skipjack tagged as described above sounded immediately upon release. On a few occasions they were seen to lead fish from the accompanying school away from the stern of the vessel. While some tagged fish left the school when released, there were indications that others remained in the same school from which they were caught. In one instance a fish released with a white type G tag was observed accompanying the vessel with part of the school for 4½ hours.

RELEASES

Between May, 1954, and July, 1956, 1,961 skipjack were tagged with the California type G tag and released in Hawaiian waters (Fig. 2).[2]

Most of the releases were within the area of the Hawaiian skipjack fishery; a few were released outside this area. This release pattern was followed in order to (1) establish the rate of recovery within the fishery, (2) study the movements of skipjack within the fishery, and (3) ascertain the direction from which skipjack approach Hawaiian waters.

It should be pointed out that the tagged fish were smaller than the usual size (18–22 pounds) composing the season's commercial landings. Eighty-five per cent were 10 pounds or smaller, 14 per cent between 11 and 20 pounds, and only 1 per cent larger than 21 pounds. The small percentage of releases in the larger size categories is due partly to the difficulty in handling these fish, and partly to the general scarcity of large fish when most of our tagging was done.

PUBLICITY PROGRAM

Publicity is an important part of most tagging programs, because one way to maximize the returns is to minimize the loss of tags recovered but not noticed by persons unaware of the program. We conducted personal interviews with skipjack fishermen on all islands and distributed posters to major fishing companies, fishing supply centers, and ports throughout the Hawaiian Islands. Fishermen were also informed of our tagging activities through radio broadcasts, transmitted by POFI vessels during their cruises in Hawaiian waters, and through informal letters. Also, wardens of the Hawaiian Division of Fish and Game stationed on the various islands were furnished photographs of tagged skipjack, together with standard recovery information forms. Because of the distinctive appearance of the tag, the publicity program, and the extensive handling of individual fish (when caught, during stowage and unloading of catch, and during butchering at the cannery), the possibility of loss of tags through nonrecognition of tagged fish was considered negligible.

Rewards for the return of tags were not part of the recovery program. Instead we purchased the tagged fish at a price slightly above the market value. A letter giving pertinent information was also sent to the person, or persons, involved in the recovery.

RECOVERIES

Of the 1,961 skipjack tagged and released, 9 were recovered by the commercial pole-and-line fishery and 3 from the stomachs of large longline-caught tunas between July, 1955, and February, 1956. The areas of release and recapture for these 12 skipjack are shown in Figure 3 and listed in Table 1. The low rate of recovery, 0.6 per cent, may be attributed in

[2] In addition, 20 skipjack were tagged with white type G tags and released in the vicinity of the Line Islands, and 12 with blue type G tags northeast of Midway Island.

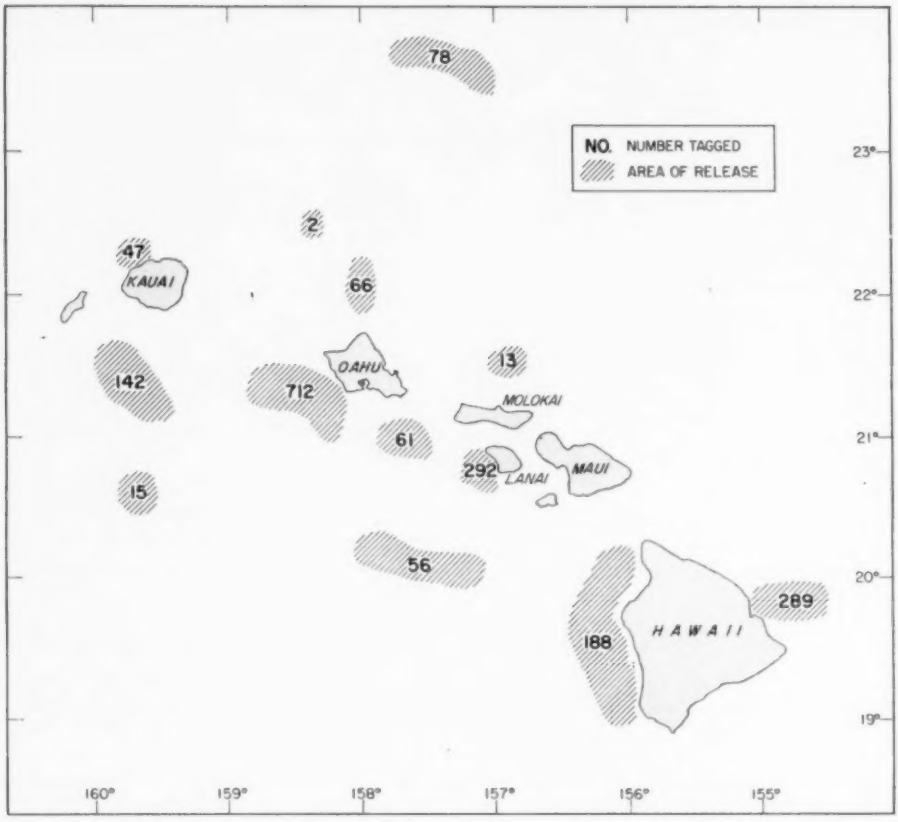

FIG. 2. Skipjack releases in Hawaiian waters, May 1954–July 1956.

part to a combination of the following factors: (1) the initial tagging mortality resulting from handling in the tagging process may have been high; (2) mortality caused by predation of large tunas and spearfishes may have been excessive; and (3) certain groups of tagged skipjack may have moved out of the area covered by the fishery.

Condition of Tags and Fish: The condition of the tag and of the skipjack was noted for each of the 9 pole-and-line caught recoveries. One fish, recaptured after only 6 days at liberty, showed quick recuperation. The tag wound appeared raw and enlarged but there were no signs of infection. Another skipjack, retaken 12 days after tagging, had new skin forming around the edges of the tag wound.

Most of the recovered fish showed a slight chafing of the anterodorsal margin of the caudal fin, caused by the free ends of the tag striking the fin. This could be prevented by trimming the ends of the tag after the knot was tied.

One skipjack recaptured 252 days after release bore only the outer jacket portion of the tag. This protruded from the right side of the fish. The wound on the left side had

TABLE 1
POFI SKIPJACK RECOVERIES WITH WHITE CALIFORNIA TYPE G TAG

ORDER OF RECOVERY	WEIGHT RANGE OF SCHOOL AT RELEASE	DATE TAGGED	DATE RECOVERED	DAYS OUT	DISTANCE TRAVELED	WEIGHT AT RECOVERY	REMARKS
	Lbs.				Miles	Lbs.	
1	5–10	6/1/55	7/12/55	41	0	3–4½	Recaptured from one school
2	6–8	6/8/55	7/12/55	34	0	3–4½	
3	3–5	7/20/55	7/26/55	6	40	4	
4	5–8	7/18/55	7/30/55	12	0	6	
5	3–6	8/22/55	8/24/55	2	6	3½	Found in stomach of longline-caught 189-lb. yellowfin
6	3–5	7/20/55	8/28/55	39	17	4	
7	4	8/17/55	8/17–8/26/55	0–9	0(?)	–	Tag only found in stomach of longline-caught 190-lb. yellowfin
8	3–5	8/25/55	8/25–9/1/55	0–7	0	4	Found in stomach of longline-caught 209-lb. bigeye
9	4–5	8/8/55	8/29/55	21	14	3½	Recaptured from same school
10	4–5	8/8/55	8/29/55	21	14	3½	
11	4–5	8/8/55	10/29/55	82	9	4½	
12	5½–9½	5/25/55	2/1/56	252	30	14	

healed completely and was marked only by a black spot on the skin (Fig. 4). Adhesion between the flesh and the plastic held the tag in place.

Movement: All of the skipjack recovered were small (3 to 10 lbs.) when tagged. They showed surprisingly little movement, all of them being recaptured within 40 miles of the point of release (Fig. 3 and Table 1). There was no inter-island movement of tagged fish. The probability of recovery of tagged skipjack in offshore waters (beyond 50 miles from land) is low because very little fishing is done in this area. However, each of the main Hawaiian islands has fisheries within 20 miles of shore, so this lack of evidence of inter-island movement cannot be attributed to the distribution of fishing effort.

Two of 39 fish (Table 1, recoveries 9 and 10) released in one group were recaptured 3 weeks later from a single school, indicating that a school of skipjack retains its identity as a unit for some time. Recoveries 3 and 6 tagged on the same day and from the same school, may provide an example of the usefulness of this hypothesis. This school may have traveled 63 miles between July 20 and August 28, 1955; 40 miles to where No. 3 was retaken, and 23 miles back to where No. 6 was retaken. Similarly, the group in which recoveries 9, 10, and 11 were released may have traveled a minimum of 37 miles between August 8 and October 29, 1955. These are straight-line distances, and in all likelihood a much greater distance was covered during this period.

Growth: Information concerning the rate of growth of skipjack was gained from a tagged fish which weighed 14 pounds when recovered after 252 days (8.4 months) at liberty. Based on the average weight of fish (7 pounds) and the size range of fish (5.5 to 9.5 pounds) in the school at the time of release, a comparison may be made with the growth rates obtained by Brock (1954) in his length frequency studies. If this tagged fish was at the lower end of the size range (i.e., 5.5 pounds) when tagged, it grew at the rate of about 1.0 pound per month. This closely approximates Brock's estimate of 1.2 pounds

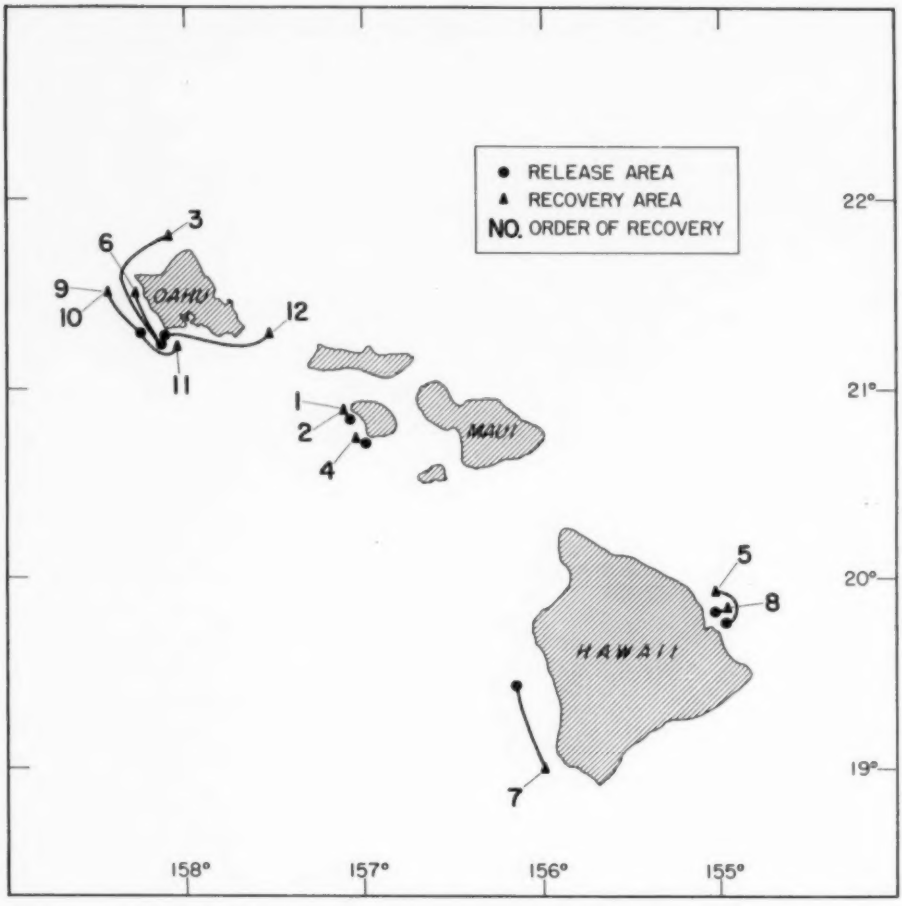

FIG. 3. Skipjack recoveries in Hawaiian waters, July 1955–February 1956.

per month for skipjack of this size (from his fig. 2). If the fish was of average size (i.e., 7 pounds) at the time of release, then a growth of 0.8 pound per month is indicated, which is slightly more than one-half the growth of 1.4 pounds per month shown by Brock. Finally, if the fish was at the upper limit of the size range (i.e., 9.5 pounds), it grew at the rate of 0.5 pound per month, or one-third the rate of growth of 1.5 pounds per month indicated by Brock.

Predation: There was evidence that some loss of tagged skipjack resulted from predation. Two tagged skipjack and one tag were recovered through incidental examination of stomachs of large tuna caught by longline near the island of Hawaii (recoveries 5, 7, 8 in Table 1). All three skipjack weighed about 4 pounds and were recovered within a few days of release. They were the only recoveries of skipjack released in that area.

In order to determine the incidence of skipjack, tagged or untagged, in the stomachs of larger fish, a sampling program at the

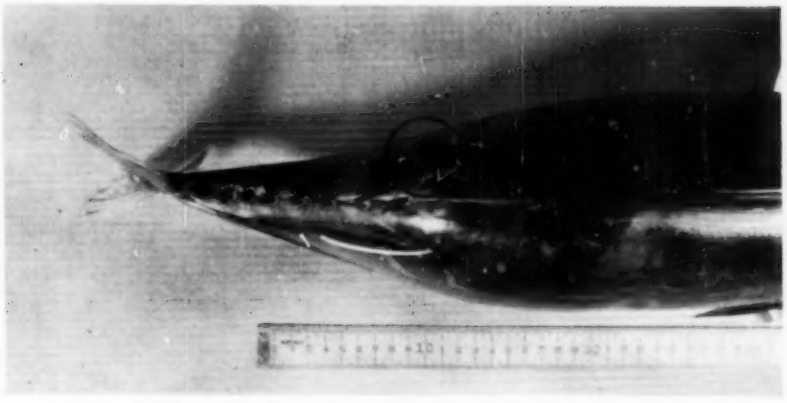

FIG. 4. Tagged skipjack recovered 252 days after release with only the jacket portion of the tag still in place. Dorsal view showing healed wound (dark area in circle) on the left side. Photograph by E. D. Stroup.

Honolulu auction markets was carried out between October, 1955, and June, 1956. During this interval, which included periods when skipjack were being tagged and released within the fishery, stomachs were examined from 538 bigeye (*Parathunnus sibi*), 103 yellowfin, 128 striped marlin (*Makaira audax*), and 74 black marlin (*Makaira ampla*) taken in the Hawaiian longline fishery. Twenty-eight of these stomachs (3.3 per cent) contained a total of 30 skipjack, none of which was tagged. Furthermore, only 9 of the 30 skipjack were as large as those being tagged, i.e., 2 pounds or larger, and the rest were estimated to be 1 pound or less. Only one large skipjack was taken from the stomach of a tuna; the others were from black and striped marlins. Unfortunately, there are no comparable data concerning the number of untagged skipjack from stomachs at the time the three tagged fish were found, but on the basis of subsequent sampling it seems that there was a higher rate of predation on tagged than on untagged fish.

SUMMARY

A tagging project was inaugurated to study migrations and to supplement our knowledge of growth of skipjack in Hawaiian waters.

During the period 1954–1956, California type G tags were attached to 1,961 skipjack released in Hawaiian waters. The majority of these fish weighed less than 10 pounds.

Only 12 or 0.6 percent of these fish were later recovered. This low recovery rate may be attributed to tagging mortality, predation, and movement out of the fishery.

The longest interval between release and recovery, by pole-and-line fishing, was 252 days and the shortest interval was 6 days.

Net movement was limited to 40 miles or less and no inter-island travel was shown.

The tag wounds on recovered skipjack were enlarged but well healed after 12 days. When used on smaller fish, the free ends of the tag caused chafing of the anterodorsal margin of the caudal fin.

One skipjack weighing 14 pounds at recovery grew at an estimated rate of 0.8 pound per month over an 8½-month period.

Predation by large tunas and spearfishes may be greater on tagged than on untagged skipjack. This conclusion is based on the recovery of three tagged skipjack from the stomachs of large tuna.

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The Synonymy of the Viviparous Polychaete *Neanthes lighti* Hartman (1938) with *Nereis limnicola* Johnson (1903)

RALPH I. SMITH[1]

Nereis limnicola was described by Johnson (1903) from the fresh-water Lake Merced in San Francisco, California. Since that time no reports of its occurrence have been published. Hartman (1938) noted that the boundaries and bed of the lake have been "altered by dredging and roadbuilding operations, and that what was once the type locality of *Nereis limnicola* now lies many feet below a road bed." In 1938 Hartman described *Neanthes lighti* from small estuaries on the coast of Marin and Sonoma counties to the north of San Francisco, and from pools described as fresh along the Russian River. In this paper Hartman mentions *N. limnicola*, but does not discuss the possibility of the two forms being synonymous. Later she has stated (Light *et al.*, 1954: 88) that *N. lighti* "may prove to be *Nereis limnicola* . . . ." In 1941, *N. lighti* was found to be viviparous by Dr. Marian Pettibone (reported by Hartman, 1944: 252), and an account of its embryology has been given by Smith (1950). Since viviparity and the ability to live in fresh water are rare among polychaetes, and since *N. lighti* seems to offer excellent experimental material, it is important that its identity be clearly established.

In recent years, reports of the existence of fresh-water nereids in Lake Merced have reached us, and search revealed them. A viviparous nereid answering the descriptions of *N. limnicola* and *N. lighti* has been found in abundance in a sandy beach on the northern shore of the northern part of what was originally the single lake. The type locality described by Johnson ("the outlet of a 'slough' on the eastern shore of the southern arm of the lake") has indeed been filled for a roadbed, as Hartman stated, and yielded no specimens, although further search at lower water levels may reveal them; the present substrate is not especially favorable.

The finding of this material makes possible a comparison of *N. limnicola* and *N. lighti*. Johnson's description (1903) fits both species well, except that he did not notice viviparity in *N. limnicola*. Hartman's description (1938) also fits both, except that she did not observe in *N. lighti* a feature remarked upon by Johnson (1903: 210), namely, the presence in posterior neuropodia of a "stout, falcate type of setae . . . in which the appendage is firmly anchylosed to the shaft, the whole forming one continuous piece." As for the first discrepancy, it is clear that the Lake Merced population is viviparous, precisely in the fashion described in the Salinas River population of *N. lighti* by Smith (1950), and subsequently observed in populations from other localities along the coast as far north as the Canadian border. As for the second discrepancy, in 1951 the writer examined, in the U. S. National Museum, two specimens of *N. limnicola*, Cat. no. 5166, collected in Lake Merced on Oct. 29, 1895, by H. P. Johnson, and labeled as "type specimens." At that time I also inspected the type lot of *Neanthes lighti* Hartman, USNM Cat. no. 20537. The fused setae as described by Johnson are present in both groups of specimens, as they are in all *N. lighti* of the writer's collections, and the parapodia of both lots answer Johnson's de-

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scription; there is not the marked reduction of the median lobe in posterior parapodia mentioned by Hartman. Hence there is no reason to doubt that the two are identical, and that the viviparous nereid commonly called *Neanthes lighti* should be known as a synonym of *Nereis limnicola* Johnson (1903).

Since the viviparity of *N. limnicola* is the consequence of hermaphroditism making possible internal self-fertilization (Smith, 1950), *N. limnicola* must be regarded as an entity reproductively isolated from certain nonviviparous but morphologically very similar species. A more extended discussion of the implications of this contention is to appear elsewhere (Smith, 1958).

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On a New Species of *Caligus* (Copepoda Parasitica) from the Coast of California

SUEO M. SHIINO[1]

AMONG THE MATERIAL of parasitic copepods which Dr. W. L. Klawe of the Inter-American Tropical Tuna Commission collected from fishes in the eastern Pacific and sent to the author for identification, there was an interesting specimen representing a new species of the genus *Caligus*. The specimen, consisting of a single female, was obtained off the coast of California. It has been preserved together with the host, *Engraulis mordax*, to whose body it was firmly clinging. The present note contains the description of this parasite.

The author wishes to express his thanks to Dr. Klawe for providing the present material, and takes a great pleasure in associating the name of the species with the naturalist.

Caligus klawei sp. nov.
Figs. 1–3

A female found on a specimen of *Engraulis mordax* 7.9 cm. long, taken off Coronado Hotel, San Diego, California, late in May, 1956. It was clinging to the side of the host above the pectoral fin. The anterior region of the body is lapped by a fleshy fold which is an abnormal outgrowth of host skin caused by the presence of the parasite.

Body flattened, length excluding rami 5.46 mm., carapace excluding marginal rim 2.39 mm. × 1.71 mm., fourth thoracic segment 0.21 mm. × 0.61 mm., length of exposed region of same 0.07 mm., genital segment 2.47 mm. long on midline, 2.89 mm. long in lateral region, 2.25 mm. wide, abdomen 0.56 mm. × 0.61 mm. Color whitish in formalin, without pigment.

Carapace elongate oval, about three quarters as wide as long, somewhat more strongly convex above than in ordinary case, with lateral regions turning downward. Two sides very widely curved and fringed by relatively narrow rim. Frontal plates two thirds the width of carapace, only slightly arched on margin and provided with a lunule close to each lateral end. Median lobe half as wide as the carapace at its base, and about as long as it is wide. It is roughly trapezoid in shape, with well-rounded corners, and extends considerably beyond the lateral lobes. Sinuses between adjoining lobes are shallow and narrow, opening backward. The transverse dorsal rib is placed at about the center of the carapace, and arches forward to make, together with the incurved posterior halves of the longitudinal ribs, a continuous semicircle. Anterior halves of the latter extend diagonally outward, separating narrower lateral areas from the broader central area, in the center of which the eyes are located. Fourth thoracic segment is covered by carapace in front and by genital segment in the rear, showing merely a very short central region in dorsal aspect. Genital segment is a huge quadrangular segment which is produced backward on either side of abdomen into a pair of oval lobes. Anterior end is contracted into a short neck, but expanded just behind this abruptly to form gracefully round shoulders which continue back to slightly arched lateral margins. Segment as long as carapace on the midline, but one fifth longer on the lateral region; width across middle of segment is one and one third that of carapace. Abdomen is about a quarter of preceding segment in length, beyond whose lateral lobes it extends only a little. It is one-segmented, as long as wide, and has slightly undulated sides and V-shaped caudal margin.

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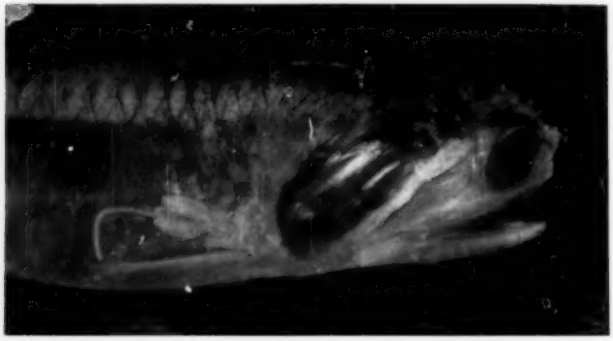

FIG. 1. *Engraulis mordax* infected by *Caligus klawei* sp. nov. × 2.5.

First antennae two-jointed as usual. Apical joint ends in several delicate hairs and two thicker spines, and bears a solitary hair at about the center of its side. Basal joint triangular and fringed by three or four rows of stout pinnate spines on frontal margin. Lunules semicircular, truncate on front side. Second antennae three-jointed. Terminal joint sharp, strongly curved and carrying two tiny spinules, one at the base and the other a short distance distally. Basal joint armed with a pointed, spurlike posterior process. Mouth tube has broad apex, enclosing slender mandibles well dentate on their curved apical blade. First maxillae small in size, apex hooklike, base oblong and furnished on the surface with two delicate hairs, each arising from a papilla. A similar hair present on the sternum behind the maxilla. Second maxillae broad at base, slender toward tip and directed straight backward; exopodite made up of one longer and two shorter spines. First maxillipeds slender; terminal joint longer than basal joint, ending in two unequal claws with finely pectinate, narrow rims and carrying a narrowly triangular accessory lamina a short distance behind. Second maxillipeds cheliform, moderately stout. Their palm fusiform, about thrice as long as wide and with a very slight bulge at about the center of inner margin. Finger straight in its basal half, but terminating in a strongly curved, sharp claw which acts against the bulge of the palm. Claw bears two short spines at its base. Sternal furca V-shaped, branches uniform in breadth, blunt at tip and without marginal rim.

First swimming legs provided with triangular rudiment of endopodite. Protopodite of second legs indistinctly divided into two joints. Two rami of third legs widely separated from each other by a crescentic dilatation of basal apron; exopodite two-jointed, whereas endopodite is practically one-jointed, owing to almost complete reduction of basal joint. Fourth legs uniramous, having protopodite longer than two-jointed exopodite. Arrangement of spines and setae present in each of four pairs of legs is shown in Table 1.

Of the apical spines on the first legs, the middle two are deeply forked into parallel, unequal branches; the external branch is shorter and has fine pectination on the sides. The outermost of them is bifid to a very slight extent, and the innermost is simple and more than once the length of the others. Plumose spines borne on the third joint of first legs, on the exopodite of second legs, and on the first endopodite joint of the latter are rimmed on one side for some distance from the base by hairs which are shorter but stiffer than those fringing the opposite side and other regions. The similar spine on the protopodite of second legs is dilated at the base into a semicircle, where it bears stiff hairs

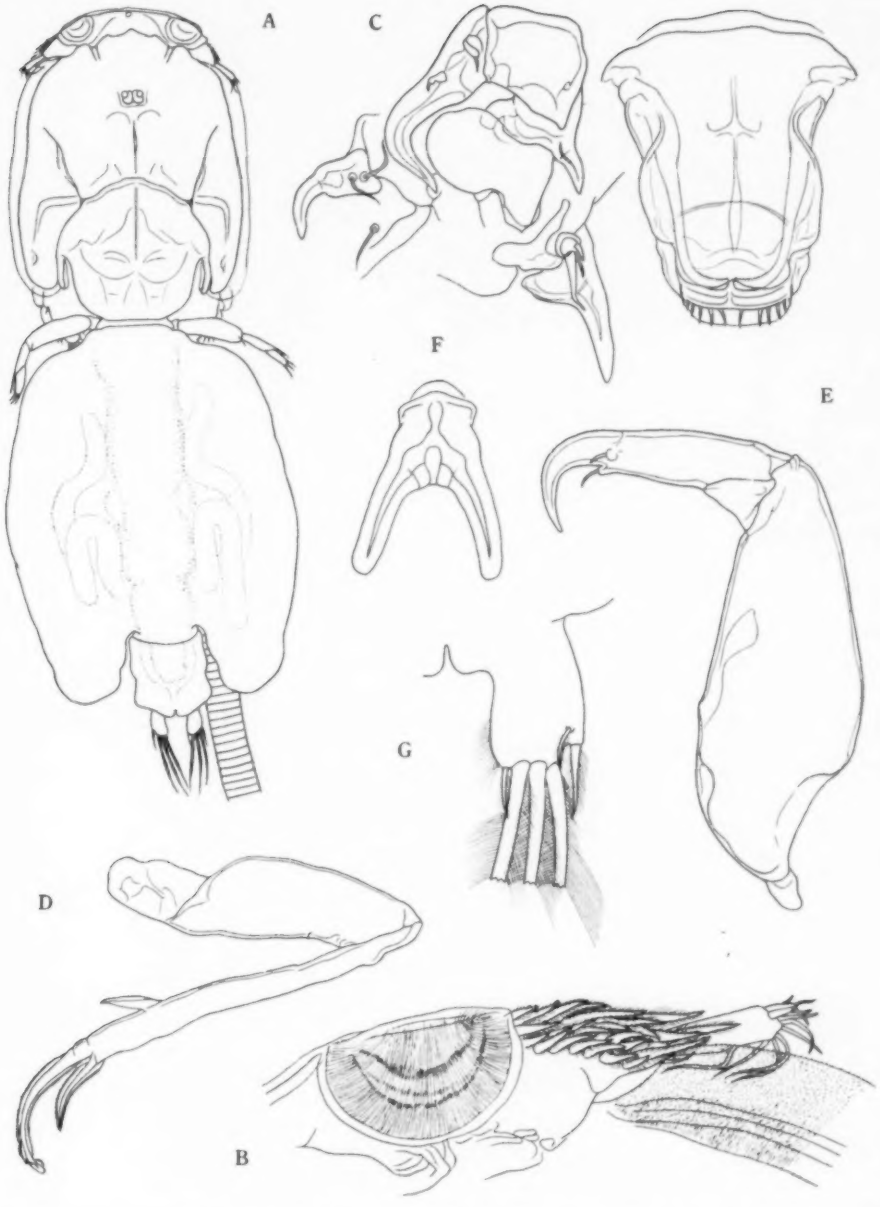

FIG. 2. *Caligus klawei* sp. nov. A, female, dorsal aspect; B, first antenna with lunule; C, second antenna, mouth tube and first and second maxillae in situ; D, first maxilliped; E, second maxilliped; F, sternal furca; G, uropod. A × 19, B-G × 100.

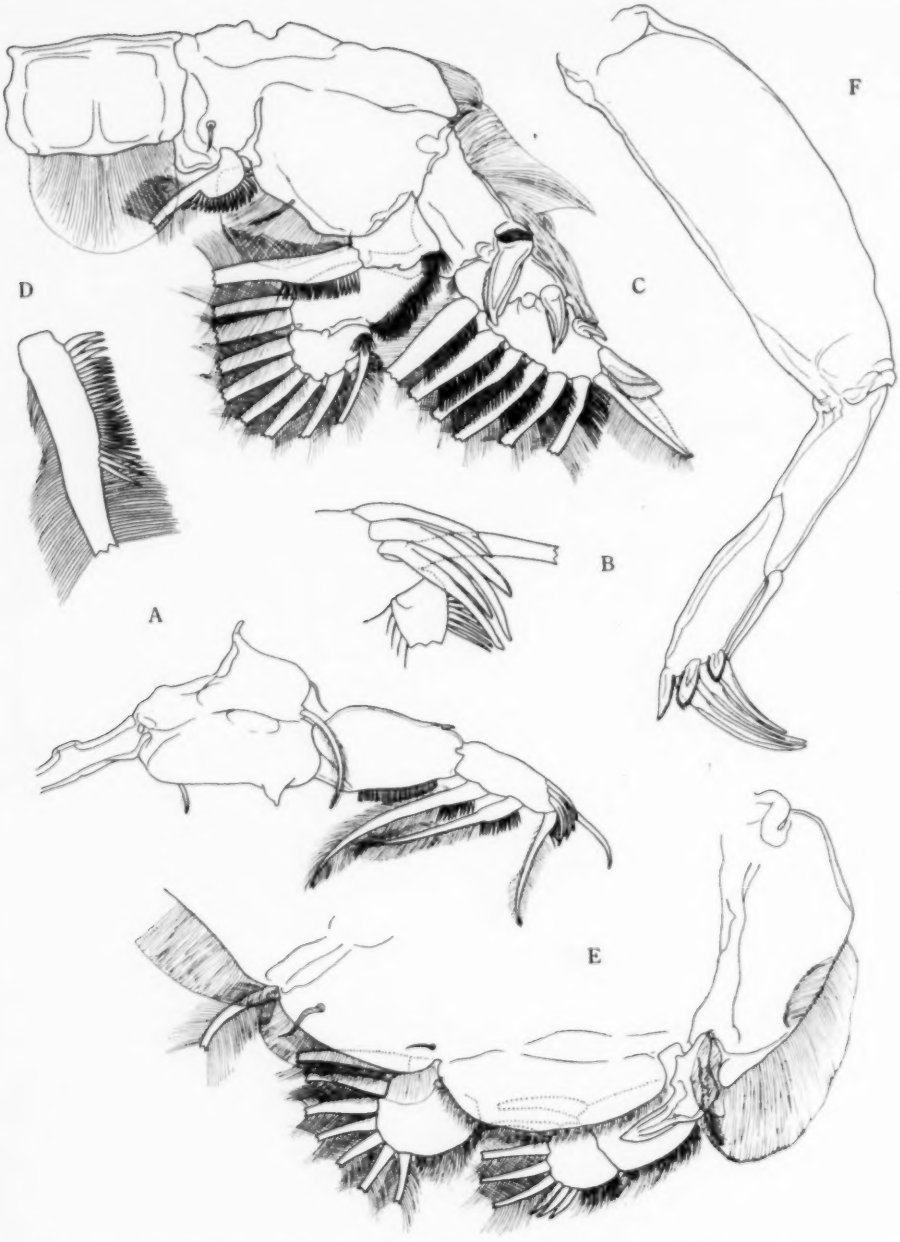

FIG. 3. *Caligus klawei* sp. nov. A, first swimming leg; B, apex of same; C, second leg; D, one of the spines on the exopodite of same; E, third leg; F, fourth leg. A, C, E, F × 100; B × 340; D × 170.

TABLE 1
ARMATURE PRESENT ON SWIMMING LEGS

LEG	BORDER	STERNAL PLATE	PROTOPODITE		EXOPODITE			ENDOPODITE		
			I	II	I	II	III	I	II	III
I	outer inner		1s, 1p 1p		1rh c	3H, 1H 3P				
II	outer inner	f	1s, 1P	f, 1s f, 1s	f, 1H c, 1P	1H c, 1P	2H, 1Q 5P	c 1P	CC c, 1P	c 6P
III	outer inner	f	f, 1p 1P, f, 2s, c		1H′, c c, 1P	c, 3h 4P		1P	c 6P	
IV	outer inner				1H	3H				

Abbreviations: c, row of hairs; CC, area covered with spinules; f, membraneous flange; H, stouter simple spine; h, feebler simple spine; H′, hooklike spine; P, stouter plumose spine; ph, feebler plumose spine; Q, spine rimmed with hairs on one side, with membrane on the other; rh, tiny spine; s, solitary hair. Roman numerals represent the ordinals of legs or of joints and Arabic numerals denote the number of spines, or of other armature present on each of them.

the same as those on the spines just named. External spine on the first two exopodite joints of the same legs acuminates toward the tip and has pectinate rims along two opposite borders; that of the first joint accompanies a basal lamina with parallel striation on its surface. The basalmost of external spines on the third joint of the same exopodite is much reduced in size, without rim; the middle spine has a broad striated membrane on the inner side, and the terminal one bears an inner row of hairs besides the outer membrane. Basal hook on the exopodite of third legs ends in a straight apex which is narrowed to a point resembling an arrowhead. Terminal spines on the fourth legs are equal in length except the outermost, which is slightly shorter; all of them are doubly edged with a narrow rim and associated at the base with a fusiform lamina, circumscribed with pectination. Spine on the second joint is simple and devoid of basal lamina. Genital segment lacks any trace of fifth legs. Caudal rami are small in size and terminate in three plumose spines, which are attended outside with two similar, but much shorter, spines and inside with another short one. Inner margin of the rami is fringed by a short row of hairs. Egg strings are longer than the body and packed with uniserial, flattened eggs.

REMARKS

The new species is characterized, above all, by the enormous size of its genital segment, which surpasses the carapace in length and width. In the genus *Caligus*, there are a number of species which present certain resemblances to the new species in the outline of this segment, in its size relative to that of the carapace, and in the possession of a small one-segmented abdomen. To facilitate distinction of *klawei* from such species some of the characters are summed up in Table 2.

As may be seen from this table, no species has a genital segment so strongly expanded as that of *klawei*. It is, however, close to *polycanthi*, *glandifer*, *fistulariae*, and *macarovi* in the outline of this segment. The first of these has the second maxillipeds stouter than in *klawei*, the second has the same limbs feebler, and the others are longer in the abdomen, which in them extends considerably beyond the foregoing segment.

The specimen will be preserved in the museum of the Prefectural University of Mie.

TABLE 2
COMPARISON OF *Caligus klawei* WITH ALLIED SPECIES

	G.L/C.L	G.W/C.W	FOURTH LEG	
			Number of joints of exopodite	Number of spines
alalongae Kröyer (after Kirtisinghe)[1]	1.00	0.66	3	0), 1, 1, 3
alatus Heegaard	0.70	0.77	2	0), 1, 3
bicycletus Heegaard	0.92	1.00	3	0), 1, 1, 3
fistulariae Yamaguti	0.86	0.82	2	0), 1, 3
glandifer Shiino	0.81	0.68	2	1), 1, (1) 3
macarovi Gussev[2]	0.77	0.87	2	1), 1, 3
minimus Otto (after Brian)	1.00	0.73	2	1), 1, 3
polycanthi Gnanamuthu	0.66	0.77	2	0), 1, 3
zei Norman and Scott	0.71	0.76	2	1), 1, (1) 3
klawei sp. nov.	1.21	1.31	2	0), 1, 3

C.L = length of carapace; C.W = width of same; G.L = length of genital segment; G.W = width of same. Proportion of genital segment and carapace is taken from the drawings given by the original authors unless otherwise indicated. Numerals shown in the rightmost column represent from the left to the right the number of spines on each of joints from basal to apical in due order. They denote, when put in parentheses, the spine borne on the outer border of joint, otherwise the terminal spines. Presence or absence of spine on the protopodite is indicated by 1) or 0).

[1]Kirtisinghe's *alalongae* does not seem conspecific with Kröyer's.

[2]*C. fulvipurpureus* Shiino is a synonym of *macarovi*.

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Intraspecific Variation in the Purple Secretion of the California Sea Hare, *Aplysia californica* Cooper

LINDSAY R. WINKLER[1]

THE SEA HARE is probably best known because of the red to purple fluid secreted from the margin of its mantle. There is only a superficial resemblance between this secretion and that of the genus *Murex*, which is the source of the anciently famous dye, "Tyrian" or "Royal Purple." Aplysia purple, however, found no practical use, probably because of one important deficiency—it turns a dirty brown upon exposure to air and sunlight.

Our knowledge of the nature and composition of aplysia purple has been increased periodically since DeNegri (1876) presented a series of beautifully colored spectra. The most significant of the early papers is that of MacMunn (1899), who attempted an analysis but concluded that there was no reason to believe that aplysia purple was composed of more than a single component. Durrien and Turchini (1925) published a minor observation which, unfortunately, was recognized as the oldest literature on the subject by some later authors. Schreiber (1932) presented the results of an extensive study of aplysia purple. He divided the purple into two components, one of which he showed to be a substance similar to urobilin and the other its precursor substance, which is also pigmented but very unstable. Fontaine and Raffy (1936) made suggestions as to the possible source of the pigment molecules from the food of the sea hare. Lederer and Huttrer (1942) used chromatographic columns to separate the two components found in the pigment. Fox (1953) summarized the work of the three last-mentioned authors. Christomanos (1955) presented a summary of biochemical studies on the purple of a questionable species he specified as *A. depilans*. He also reported isolating a green band on his powdered sugar column from the purple of the *Aplysia* which he refers to as *A. depilans*. He was unable to obtain sufficient concentrations to produce a spectrum.

The present writer noticed that there was a gross color difference between young animals and adults of the west coast sea hare, *Aplysia californica* Cooper, the younger producing a bluer, the older a more reddish secretion. Experiments to test the cause of this phenomenon led to more basic studies of the composition and instability of aplysia purple.

MATERIALS AND METHODS

To obtain aplysia purple uncontaminated by salt water, specimens of *Aplysia californica* Cooper at Lunada Bay, Palos Verdes, California, were caught and the mantle area was rinsed with distilled water. This usually caused sufficient irritation to stimulate flow of the secretion but not enough to cause the opaline gland to discharge its contaminating viscous protein material. The aplysia purple was caught in small vials, to each of which a

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drop of hydrochloric acid was added to prevent degeneration. The material was returned to the laboratory where it was refrigerated or frozen for long-term storage. Spectrophotometric curves and chromatographic separations were made using 10 per cent hydrochloric acid as diluent. Spectrophotometric curves were run on a Beckman Model DU spectrophotometer.

The writer used two methods of analysis. Chromatographic columns were prepared, using corn starch packed in a column two feet deep, in four-foot sections of soft glass tubing (⅛ in., outside diam.). A very small piece of glass wool at each end of the column held the corn starch in place.

The tube was placed in a stopper which in turn fitted into a suction flask. Approximately one half cc. of aplysia purple was placed in the top of this column. As soon as the substance had penetrated the column, the top of the tube was filled with 10 per cent hydrochloric acid and suction was applied to the base of the column. About 8 hours later, when pigment had reached the bottom, the tube was removed and cut into sections corresponding with the color components. The starch was removed and the color components were eluted with dilute hydrochloric acid. Instead of cutting up the column, suction can be continued and each fraction can be caught as it drips from the bottom of the column. This method is very slow, requiring several days for one complete separation.

It was found that quicker determinations, especially where it was unnecessary to collect the fractions, could be made by paper chromatography. Several alterations in the methods were used, depending upon the nature and purpose of the particular investigation being carried on. Square sections of Whatman No. 1 filter paper measuring 18 × 18 cm. were spotted or lined with aplysia purple at a point 1½ cm. from the margin which would become the base. The liquid was applied with either a fine pipette or with an Esterbrook No. 2 drawlet pen. Each paper was then folded twice parallel to the line of travel of the components, after which the folds were relaxed enough so that the papers would stand without any two parts of the paper being in mutual contact. The papers were stood in petri dishes containing about ½ cm. of dilute hydrochloric acid and each paper and its petri dish was then covered with a bell jar. Separations made by this method were complete in one hour. Great care was necessary, however, in making the original spot or line. Thin lines and small spots produced the best results, especially where the distance of upward migration was limited. Strips 3 feet long were used with large initial wide lines of pigment. These resulted in excellent separations but required from 8 to 12 hours. The papers were dried and stored until the time of elution. Lining rather than spotting simplified the separation and subsequent elution. The papers were cut into strips parallel with the original pigment line so that each strip contained only one color component. Elution was then made by "siphoning" dilute hydrochloric acid lengthwise through the strips thus formed.

EXPERIMENTAL DATA

To determine the spectrophotometric differences between the purple secretion of young specimens whose purple appears bluish and that of adult specimens which is of a reddish hue, studies were made upon diluted aplysia purple. The most striking differences, as shown in Figure 1, were: (1) the differences in relative height of the two peaks, and (2) the variation of 15 mμ in the location of the broad peak in the high 500 region.

The components of the purple of *A. californica* were separated in quantity by column chromatography. Though no blue region was distinct as a separate band on the starch column, the collected fraction from the extreme trailing region of the lavender zone gave high concentrations showing a deep blue gross color, which produced a different absorption curve than that of the earlier lavender collec-

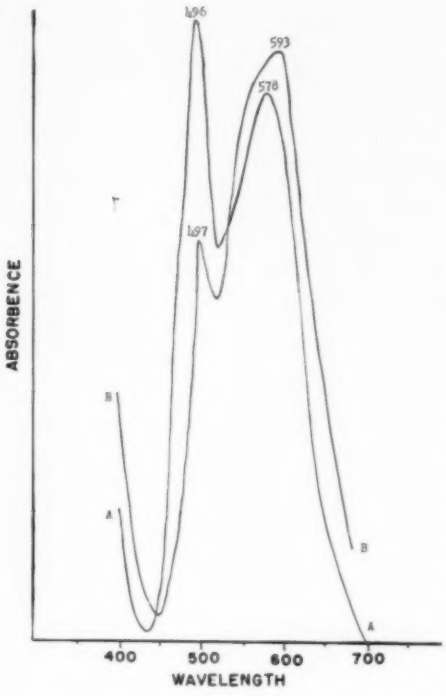

FIG. 1. The spectral curves of the aplysia purple taken from (A) a *Plocamium*-feeding adult, and (B) a young specimen showing no signs of feeding on *Plocamium*. The pigment was diluted in 10 per cent hydrochloric acid.

tions. The absorption spectrum (Fig. 2) showed a far sharper peak but a much less acute slope toward the red end of the spectrum than was noted earlier in the lavender collections. This suggested that it constituted a separate component. Paper chromatography was then tried as a means of separation, and by this it was possible to prove the existence of a third component of the aplysia ink of *A. californica*. On the dried paper a rhodonite pink component (Ridgway, 1912) left a wide band in the center of the paper. The second, a deep lavender, lagged behind at one-quarter the distance above the starting line. Scarcely clearing the initial line was a calamine blue area. Elution produced weak concentrations of the pigments, but these were adequate to produce curves on the Beckman Model DU spectrophotometer. However, these papers were dried and stored before elution, and this treatment gave opportunity for oxidative changes (Fig. 2).

DISCUSSION AND CONCLUSIONS

Though a component was isolated which gave a virtually pure curve at 496 mμ (Fig. 3), the writer has never succeeded in isolating a fractional component with a peak in the high 500 region which did not also have a weak peak at 499.5 mμ (not 496). As this material having two peaks (which will be shown to be composed of more than one, separable, but similar components) stands under refrigeration over a period of time, the relative heights of the two peaks change. The D band peak decreases and the F band peak increases in height, with a gradual shift of the F band from 499.5 to 497 and finally to 496 mμ, eventually giving approximately the same spectrum and gross color as the original aplysia purple from which it was separated (Fig. 3).

Aplysia purple is believed to be a bilin (Fox, 1953), a linear chain of pyrrole molecules connected by –CH= or $-CH_2-$ linkages, as it gives a positive Gmelin reaction. Brode (1955), by using commercial dyes, showed that the spectrophotometric effect of these linkages is insulating for $-CH_2-$ and coupling for the –CH= configaration. In *Aplysia* the pyrrole molecules of the bilins seem to be joined by the insulating linkages when in the blue state, which thus inhibits the normal F band absorption characteristic of the chain of pyrrole molecules absorbing together. In time, these insulating linkages gradually change to coupling linkages, perhaps due to enzymatic activity or other causes as yet unknown. As Brode (1955) puts it, "If the linkage is changed to a conjugating (=coupling) connection . . . there is a marked change in the spectrum with the production of a single resonance structure involving both

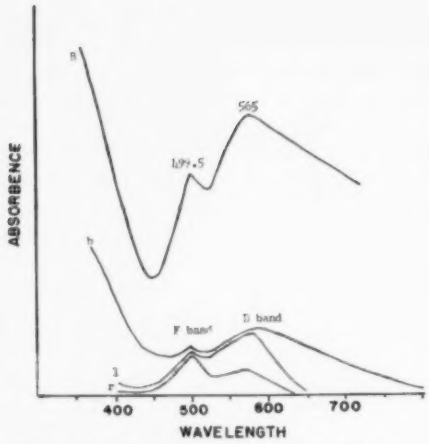

FIG. 2. Curve B shows the extreme trailing blue portion of the column chromatogram. The paper chromatographic curves are indicated by small letters. The curves of the rhodanite pink (r), the lavender (l), and the calamine blue (b) regions were read from weak solutions produced by eluting dried papers.

chromophores as a single coplaner chromophore." The curves he used as examples compare markedly with the curves of aplysia purple.

The writer has not yet found a satisfactory explanation for the instability of the D band absorption peak, which seems quite sporadic in its variation but doubtless follows well-defined laws.

Schreiber's work (1932) on the Mediterranean purple-producing *Aplysia* indicated that the peak in the F band (at approximately 500 mμ) represents the absorption by a substance similar to urobilin, and that the other peak in the high 500 region (Schreiber's broad unstable D band) represented the precursor of this substance. The above data confirm his theory.

It seems that the fast-growing young do not possess as much of the red finished product as do the adult specimens and hence secrete a larger percentage of the blue precursor substance. No basic differences other than that of relative quantity of the substance and its precursor are indicated by the spectrophotometric studies.

The condition of the individual animal is indicated as being highly influential in this respect as well. Well-fed adult specimens seem to have an excess of purple which is secreted at the slightest provocation, and often with no provocation at all.

The vertebrate bilins are derived from the breakdown of the tetrapyrrole molecules of hemoglobin. However, in plants tetrapyrrole molecules are the basis of chlorophyll. The quantities of aplysia purple produced would indicate a plentiful source such as chlorophyll, which is consumed in quantity by these algae eaters.

The bilichromes of the red algae may well be an additional rich source of the purple, as suggested by Fontaine and Raffy (1936). This is supported by the fact that adult animals feeding largely on *Plocamium pacificum*, which has a low chlorophyll but a high phycobilin content, usually produce a much greater quantity of pigment and with less provocation than those subsisting on other algae.

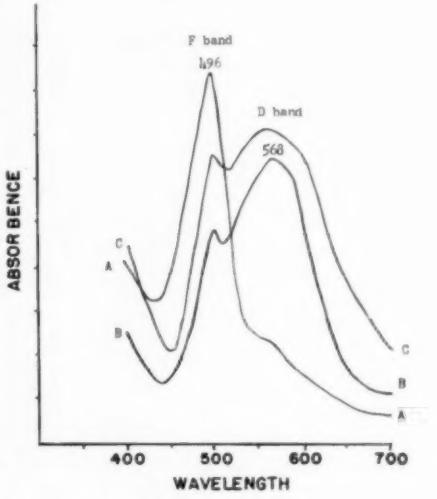

FIG. 3. The absorption spectra of the red (A), and composite lavender and blue (B) regions from the column separations. After the solution giving curve B had been in the refrigerator for two weeks it had changed its gross color and produced the curve marked C.

However, these other algae can not be the only source as the writer has kept small *A. californica* until they have approximately tripled in size while feeding them on parsley and celery tops, which contain none of the phycobilins, and he has found that they could still produce the purple secretion, though in reduced quantity.

Lederer and Huttrer (1942) followed current practice in naming the two components which they isolated from the purple of *A. punctata*. To the redder of the two components, which is the "urobilin" of Schreiber (1932), they gave the name *aplysiorhodin;* and to the bluer component, or the "urobilinogen" of Schreiber, they gave the name of *aplysioviolin*. For convenience of identification the writer gives the name *aplysioazurin* to the additional blue component he has isolated from the secretions of *A. californica*.

Spectrophotometrically, this new bluem coponent is responsible for the sharp rise in absorption below 425–450 mμ, as noted in all spectral curves produced by solutions from which it had not been removed. The rise was absent from the spectra of the other two components in the paper separations (Fig. 3).

Actually, in view of Schreiber's work (1932) aplysioviolin would be the precursor of aplysiorhodin. It is not yet evident what the role of aplysioazurin may be.

SUMMARY

From the foregoing discussion of aplysia purple the writer proposes: (1) that there are two apparent absorption peaks in the spectrum of aplysia purple from *Aplysia californica* when hydrochloric acid is used as the solvent; (2) that the relative height of these two peaks indicates the proportion of precursor to finished product in the purple from an individual specimen; (3) that the gross color varies widely from animal to animal; (4) that column chromatography as used here is superior for large scale separations but poor for qualitative separation; (5) that paper chromatography is more sensitive and is superior for quick qualitative isolation of components into individual zones; and (6) that the purple of *A. californica* contains a third component, *aplysioazurin*, in addition to the major components, *aplysiorhodin* and *aplysioviolin*.

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Spiders from Some Pacific Islands, III
The Kingdom of Tonga

B. J. Marples[1]

The Kingdom of Tonga consists of some 200 islands occupying an area in the southwest Pacific bounded by latitudes 15°S. and 23°31′S., and by longitudes 173°W. and 177°W. The islands fall into three groups, Vava'u in the north, Ha'apai in the centre, and Tongatabu in the south, the overall length being about 175 miles. All the islands are small; Tongatabu Island, 25 by 10 miles, is much the largest, and the total area is about 385 square miles. Most of them are elevated coral reefs and so are very low and flat. The highest point of Tongatabu Island is only 60 feet above the sea. A few are volcanic islands, and one of these reaches a height of 3,380 feet. During the year the maximum temperature varies between about 75°F. and 85°F., and there is a rainfall of about 80 inches. Hurricanes occasionally occur. The principal adjacent island groups are Fiji to the west and Samoa to the north, each 200 or 300 miles from Tonga.

Spiders have been described previously from Tonga by Koch (1872), Berland (1934), and Marples (1955). Apparently, no spiders have been collected on the high islands. The present collection consists of 34 species, and brings the total now recorded from 31 to 49 species. Of the spider fauna of adjacent island groups that of Samoa with 128 species is the best known. Sixty-six are recorded from Fiji, and, though unpublished records bring the total to 92, there are very many more to be found. The present list for Tonga is also doubtless far from complete, but a few comparisons can be made.

No Uloboridae are known (not even *U. geniculatus*, which is commonly found in houses), as compared with three in Fiji and six in Samoa. There are five species of Thomisids, against one in Samoa and one in Fiji, *D. praetexta* occurring in all three. The three Epeirid genera *Gasteracantha*, *Argiope*, and *Nephila* occur in Fiji and the islands to the west. *Gasteracantha* is not known in Tonga, but one species of *Argiope* is recorded from Tongatabu; this is the most eastern record for the genus in the southwest Pacific. Five species of *Nephila* are present, and the genus occurs also in Niue, some 200 miles to the east of Tonga, and doubtfully in Samoa. Of the 49 species recorded from Tonga 32 occur also in Fiji, and 32, not all the same species, occur also in Samoa.

I am indebted to my wife and son for collections of 14 species from each of the islands, Tongatabu and Vava'u. The greater part of the collection was made on various islands by Dr. N. L. H. Krauss, and I am grateful to him for the opportunity of examining it. The specimens will be deposited in the Bernice P. Bishop Museum in Honolulu.

In the descriptions the measurements were made with an eyepiece micrometer and are given in millimetres. The leg indices are derived by dividing the length of each leg by the length of the carapace, and the tibial indices, which give a measure of the stoutness of the legs, by dividing the combined lengths of the patella and tibia by the proximal breadth of the patella. The eye measurements are given in direct scale readings, so they indicate proportions only.

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LIST OF THE SPECIES RECORDED FROM TONGA

(T = Tongatabu, H = Ha'apai, V = Vava'u)

DICTYNIDAE

Dictyna bifasciata. V.

OONOPIDAE

Gamasomorpha loricata ? V.

SCYTODIDAE

Scytodes marmorata. T,V.
S. striatipes. T,H,V.

PHOLCIDAE

Pholcus ancoralis. T,V.
Physocyclus globosus. T.
Smeringopus elongatus. T.

CLUBIONIDAE

Chiracanthium diversum. T,V.
C. furax. T,H,V.
C. longimanum. T.
Clubiona alveolata. T,V.

SPARASSIDAE

Heteropoda venatoria. T,V.

THOMISIDAE

Diaea praetexta. T,H,V.
D. septempunctata. T.
D. tongatabuensis. T.
Hedana subtilis. T.
H. pallida. T.

SALTICIDAE

Ascyltus pterygodes. T,H,V.
Bavia aericeps. T,V.
Erasmia nigrovittata. T,V.
Hasarius insularis. T.
H. albocircumdatus ? T.
Menemerus bivittatus. T.
Mollicia microphthalma. T,H,V.
Plexippus payculli. V.
Thorellia ensifera. T,V.
Trite longipalpis. T.
Vitia albipalpis. T.

LYCOSIDAE

Lycosa tongatabuensis. T.

THERIDIIDAE

Conopistha samoensis. T.
C. unimaculata. T.
Rhomphaea cometes. T,V.
Theridion adamsoni. T.
T. albostriatum. T,V.
T. aleipata. T,V.

TETRAGNATHIDAE

Leucauge tuberculata. T,H,V.
Tetragnatha macilenta. T,H,V.
T. panopea. T.
T. keyserlingi. T.

EPEIRIDAE

Cyclosa litoralis. V.
Cyrtophora moluccensis. T,V.
Argiope plana. T.
Epeira plebeja. T,H.
E. theisi. T,V.
Nephila flagellans. T.
N. durvilla. T.
N. prolixa. T.
N. vitiana. T.
N. tetragnathoides. T.

DICTYNIDAE

Dictyna bifasciata L. Koch

4 Vava'u. New record, previously recorded from Samoa.

OONOPIDAE

Gamasomorpha loricata L. Koch

1 Female. Neiafu, Vava'u. The female is not specifically identifiable but those found throughout the Pacific are taken to be of this species. It is recorded from widespread localities, this being the first from Tonga.

SCYTODIDAE

Scytodes marmorata L. Koch

3 Female, 1 male. Neiafu, Vava'u. This has

been previously recorded from Tongatabu and is widespread in the Pacific.

Scytodes striatipes L. Koch

1 Female and 1 imm. Neiafu, Vava'u. 1 Female, 1 male. Ohonua, Eua Island, Ha'apai. Previously recorded from Tongatabu and widespread in the Pacific.

PHOLCIDAE

Pholcus ancoralis L. Koch

1 Female and 3 imm., 2 male and 1 imm. Nuku'alofa, Tongatabu. 1 Male. Neiafu, Vava'u. First records from Tonga, widespread in the Pacific.

Physocyclus globosus Taczanowski

1 Male. Nuku'alofa, Tongatabu. 2 imm. possibly this species. Vava'u. First records from Tonga, widespread in the Pacific.

Smeringopus elongatus Vinson

2 Female. Nuku'alofa, Tongatabu, whence it has been recorded. With the exception of a record from the Marquesas this species is known from the islands in the western and central regions of the south Pacific.

CLUBIONIDAE

Chiracanthium furax L. Koch

5 Female, 2 male. Nuku'alofa, Tongatabu. 1 Female, 2 male. Neiafu, Vava'u. 1 Female, 2 male. Ohonua, Eua Island, Ha'apai. Berland (1929), who described the male of *C. furax*, states that it differs from that of *C. longimanum* in having a hooked central apophysis on the palp, a condition found in all the present specimens. These two species are very similar and it seems highly likely that they are synonymous, in which case *C. longimanum* has page precedence. A difference mentioned by Koch (1872) is a dark streak on the carapace of *C. furax*, which is absent in the present specimens. *C. furax* is recorded from Samoa and Fiji, *C. longimanum* from these islands and also from Tonga, New Hebrides, and Australia. Two males, one from Tongatabu and one from Vava'u, resemble the others in palps and chelicerae but are considerably smaller, having a carapace length about 4.5 mm. instead of 7.5 mm.

Chiracanthium diversum L. Koch

1 Female, 2 males. Nuku'alofa, Tongatabu. 1 Male. Neiafu, Vava'u. One male from Tongatabu is somewhat larger and has three teeth on the promargin of the groove, as has the female. The female has not previously been described.

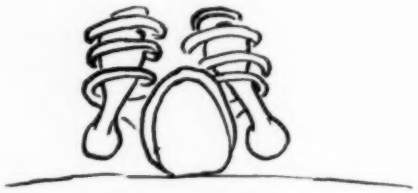

FIG. 1. *Chiracanthium diversum*. Epigynum.

FEMALE. Length 7.36 mm. Pale yellowish brown.

Carapace: Length 3.60 mm., breadth 2.40 mm. Low and smooth truncated in front.

Eyes: Eight. From above both rows slightly recurved, the anterior eyes project anteriorly beyond the carapace. Clypeus very low, about the diameter of AME. Breadth of eyegroup 1.60 mm. Ratio of eyes and of their distances apart: AM, 80; AL, 85; PM, 77; PL, 80; AM–AM, 160; AM–AL, 236; AM–PM, 115; PM–PM, 186; PM–PL, 268; L–L, 46.

Chelicerae: Large and projecting forwards, boss present, groove oblique. Three teeth on the promargin, the middle the largest. Three teeth on the retromargin, the most dorsal the largest. The dorsal promarginal tooth opposite to the ventral retromarginal one.

Maxillae: Much longer than the lip. Semicircular anteriorly, concave laterally.

Lip: Free. Longer than broad, concave anteriorly.

Sternum: Length 1.73 mm., breadth 1.37 mm. Convex. Lateral margins notched for the bases of the last three legs, anterior margin slightly concave.

Palp: Long and slender. Minute claw.

Legs:

I	II	IV	III	Palp
4.1	3.2	3.2	2.2	1.3

	FEMUR	PATELLA AND TIBIA	METATARSUS	TARSUS	TOTAL
Palp.....	1.69	1.55	....	1.34	4.59
I.....	4.18	5.26	4.14	1.17	14.76
II.....	3.42	4.00	3.13	0.95	11.51
III.....	2.34	2.81	2.20	0.76	8.11
IV.....	3.38	4.00	3.31	0.95	11.64

Tibial Index I 10.2
Tibial Index IV 8.2

Claws: Two, pectinated about 12. Tenent hairs in dense tufts on the feet and extending along the ventral surface of each tarsus and metatarsus, and sparsely on tibiae I and II.

Spines: I. One pair at the proximal end of the tibia. II. None. III. One retrolateral-distal on the tibia; 2 median and 4 distal on the metatarsus. IV. One retrolateral-distal on the tibia; 1 ventral-proximal, 2 median and 4 distal on the metatarsus.

Abdomen: Length 4.33 mm., breadth 2.48 mm. Epigynum as in figure.

Clubiona alveolata L. Koch

1 Female. Nuku'alofa, Tongatabu. 1 Male. Neiafu, Vava'u. Several immature specimens which may belong to this species, which is widespread in the Pacific but not previously recorded from Tonga.

SPARASSIDAE

Heteropoda venatoria (Linn.)

1 Female. Tongatabu. 1 Female, 2 males. Vava'u.

THOMISIDAE

Diaea praetexta L. Koch

4 Females. Nuku'alofa, Tongatabu. 17 Females, 4 males. Vava'u. 1 Female. Ononua, Ha'apai. This species was described from Samoa, where it is very variable in colour, being frequently without the dark markings. The very similar *D. septempunctata* was described by Koch from Tonga. The present specimens are pale, or sometimes with three pairs of small spots, but their reproductive organs resemble those of specimens from Samoa and they seem to belong to this species.

SALTICIDAE

Ascyltus pterygodes (L. Koch)

3 Females, 3 males, 14 imm. Tongatabu. 1 Male, 2 imm. Eua Island, Ha'apai. 7 Females, 5 males, 24 imm. Vava'u. Widespread species, not previously recorded from Vava'u.

Bavia aericeps Simon

1 Male, 3 imm. Tongatabu. 1 imm. Vava'u. First records for the Tonga group. A widespread species.

Erasmia nigrovittata Keyserling

1 Female. Vava'u. This species was described from a single female from Tonga. Keyserling does not mention the cheliceral teeth, but Berland (1934) places the species amongst the Fissidentati. Petrunkevitch (1928) lists it as a synonym of *Iona* Peckham, one of the unidentate species. The present specimen agrees well with Keyserling's description, and has four distinct teeth on each of the margins of the cheliceral groove.

Menemerus bivittatus Dufour

1 Female. Nuku'alofa, Tongatabu.

Mollicia microphthalma L. Koch

1 Female, 2 imm. Tongatabu. 1 Female. Panga, Ha'apai. 1 Male. Holonga, Vava'u. A widespread species, first records for the Tonga group.

Plexippus payculli Auduin

1 Female. Vava'u. A widespread species, first record for Tonga.

Thorellia ensifera Thorell

9 Females, 3 males. Tongatabu. 2 Females, 1 male. Vava'u. Widespread in the central and eastern regions of the Pacific as far west as Fiji. First record for Tongatabu.

Vitia albipalpis Marples

1 Male. Nuku'alofa, Tongatabu. Described from Fiji, first record for Tonga.

THERIDIIDAE

Conopistha samoensis L. Koch

2 Females. Tongatabu. Widespread species.

Conopistha unimaculata Marples

1 Female. Tongatabu. Previously recorded from Samoa and Niue, as well as Tonga.

Rhomphaea cometes L. Koch

1 Male. Tongatabu. 1 Male. Falevau Island, Vava'u. New records for Tonga. Known also from Fiji, Samoa, and Tahiti.

Theridion adamsoni Berland

1 Male, imm. Tongatabu. Probably belonging to this species, previously known from Tahiti, Austral Islands, and Samoa.

Theridion albostriatum L. Koch

1 Male. Vava'u. Widespread species, previously recorded from Tongatabu.

Theridion aleipata Marples

2 Females. Tongatabu. 3 Females. Vava'u. New record for Tonga, previously known from Samoa and Aitutaki.

TETRAGNATHIDAE

Leucauge tuberculata Keyserling

2 Females. Tongatabu. 2 Females. Vava'u. 1 Female. Eua Island, Ha'apai. Widespread in the central and eastern parts of the Pacific. Previously recorded from Tongatabu.

Tetragnatha macilenta L. Koch

2 Females and 2 imm. Tongatabu. 1 Female, 1 male. Ohonua, Ha'apai. 3 Females and 2 imm. 2 Males. Vava'u. Widespread species not previously recorded from Tonga.

Tetragnatha panopea L. Koch

1 Male. Tongatabu. Widespread species, first record from Tonga.

EPEIRIDAE

Cyclosa litoralis (L. Koch)

1 Female. Vava'u. The specimen is smaller than ones from Samoa and the epigynum is slightly different, but it seems likely to be this species. It is widespread and occurs in both Fiji and Samoa. This is the first record of a *Cyclosa* from Tonga.

Cyrtophora moluccensis Doleschall

13 Females. Tongatabu. 6 Females. Vava'u. A very widespread species.

Epeira theisi Walckenaer

2 Females. Tongatabu. 7 Females, 2 males. Vava'u. Very widespread species, new record for Vava'u.

Epeira plebeja L. Koch

1 Female, 1 male imm. Eua Island, Ha'apai. 1 Male imm. Tongatabu. This female has a mottled brownish abdomen whose shape and pattern do not resemble those of *E. theisi*, though the epigynum is similar. According to the distinctions given by Berland (1935) it appears to be *E. plebeja*, a species already recorded from Tonga and from Fiji. The two immature males probably belong to the same species.

Nephila flagellans L. Koch

3 Females, 1 male. Tongatabu. Previously recorded.

SUMMARY

A collection of 34 species from various islands in the Tonga group includes 18 new records, bringing the total to 49. The female of the clubionid *Chiracanthium diversum* is described.

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The Hawaiian Species of *Conus* (Mollusca: Gastropoda)[1]

ALAN J. KOHN[2]

IN THE COURSE OF a comparative ecological study of gastropod mollusks of the genus *Conus* in Hawaii (Kohn, 1959), some 2,400 specimens of 25 species were examined. Uncertainty of the correct names to be applied to some of these species prompted the taxonomic study reported here. Many workers have contributed to the systematics of the genus *Conus;* nevertheless, both nomenclatorial and biological questions have persisted concerning the correct names of a number of species that occur in the Hawaiian archipelago, here considered to extend from Kure (Ocean) Island (28.25° N., 178.26° W.) to the island of Hawaii (20.00° N., 155.30° W.).

FAUNAL AFFINITY

As is characteristic of the marine fauna of the Hawaiian Islands, the affinities of *Conus* are with the Indo-Pacific center of distribution. The Hawaiian Islands mark the northeastern limit of most of the species that occur there. Eastern Pacific species of *Conus* are entirely absent from the Hawaiian fauna.

Most of the species present in Hawaii range widely throughout the central and western Pacific Ocean, Indian Ocean, and Red Sea. The chief mode of distribution is the pelagic veliger larval stage. Drifting while attached to floating material may be a secondary mechanism. Despite the extensive distribution of most of the species occurring in Hawaii, the geographic position of the archipelago and the prevailing westerly surface currents are factors which could plausibly effect the isolation necessary for geographic speciation.

Of the 33 species of *Conus* considered in this paper to be valid constituents of the Hawaiian fauna, about 20 occur in shallow water on marine benches and coral reefs and in bays. Of these, only one species, *C. abbreviatus* Reeve, is considered to be endemic to the Hawaiian archipelago. Less is known of the species more characteristic of deeper water habitats. Some, known at present only from dredgings about the Hawaiian Islands, may in the future prove to occur elsewhere as well, when adequate sampling methods are extended to other parts of the Indo-West Pacific region.

ECOLOGY

Since the ecology of *Conus* has been discussed in detail elsewhere (Kohn, 1959), ecological data are restricted to notes in this report.

It is a pleasure to acknowledge the constant stimulation and willing assistance of Karl W. Greene, director, Children's Museum of Honolulu, and Edwin H. Bryan, Jr., curator of collections, Bernice P. Bishop Museum, Honolulu. The collections and libraries of the following institutions were also visited, and gratitude is expressed to the persons in charge: U. S. National Museum (H. A. Rehder, J. P. E. Morrison), Academy of Natural Sciences of Philadelphia (R. T. Abbott), Museum of Comparative Zoology, Harvard University (W. J. Clench, R. D. Turner), and Bernice P. Bishop Museum (Y. Kondo). In addition, specimens were loaned to the writer for study by C. A. Allen, Mrs. Jean Bromley,

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Mrs. A. M. Harrison, W. C. Ross, and C. S. Weaver. Valuable assistance rendered by Charles E. Cutress in preparation of the color photographs is gratefully acknowledged. Most of the work was carried out at the Osborn Zoological Laboratory, Yale University, during tenure of a fellowship from the National Science Foundation.

BIBLIOGRAPHICAL NOTES

An excellent bibliographical account and collation of the major works in which species of *Conus* were described is given by Hanna and Strong (1949). Except where otherwise noted, the collations cited therein are followed in the present paper.

Catalogue of the Portland Museum. 1786. This catalogue was published anonymously, but its authorship is usually attributed to George Humphrey (Dall, 1921). The names of new species are attributed to Daniel Solander in the volume, and the same usage is followed in the present paper. A valuable discussion of this catalogue is given by Wilkins (1955), who also presents cogent reasons for attributing the names to Humphrey.

J. G. Bruguière. *Encyclopédie Méthodique. Histoire Naturelle des Vers*. 1792. Many previously undescribed species of *Conus* were named and carefully described in this work. However, the authorship to be attributed to these names has been a matter of dispute almost since the volume appeared. In the volume, Bruguière attributes the names and Latin diagnoses of species to C. H. Hwass (p. 598). Bruguière states that he himself wrote the descriptions and the "additional" synonymy (see Clench, 1942: 3). New specific names are published in the volume as, e.g. "*Conus catus* Hwass."

However, many subsequent writers (Lamarck, 1810; Dillwyn, 1817; Kiener, 1845–1850; Wood, 1856; Sowerby, 1857–1858; Schaufuss, 1869; Iredale, 1929; Tomlin, 1937; Cotton, 1945; Hanna and Strong, 1949; Hirase, 1954; and Kira, 1955) have cited such species as, e.g. "*Conus catus* Bruguière." Other writers (Blainville, 1818; Reeve, 1843–1844; Adams and Adams, 1858; Weinkauff, 1874; Smith, 1879; Tryon, 1884; Fischer, 1887; von Martens and Thiele, 1903; Tinker, 1952; and Morris, 1952) have cited the names as they appear in Bruguière (1792). A third group of writers (Dautzenberg, 1937; Clench, 1942; Mermod, 1947; and Dodge, 1953) has cited such names as, e.g., "*Conus catus* Hwass *in* Bruguière."

Application of the *Règles* of the International Commission on Zoological Nomenclature (ICZN), and later provisions and clarifications of the *Règles*, does not lead to an unequivocal solution to this problem. In the decisions of the ICZN meeting in Paris in 1948, it was recommended (Bull. Zool. Nomencl. 4: 565–566, 1950) that "where in a book or paper written by one author (say author 'A') it is clearly stated that the description of one or more specified taxonomic units there named has been prepared exclusively by some other author (say author 'C'), the name or names in question are to be attributed to author 'C', not to author 'A'. The name of the taxonomic unit so described and named is to be cited by later authors as having been published by 'C in A'."

It is apparent from the remarks of Bruguière (1792: 598; see also Clench, 1942: 3) that the descriptions of the species were not prepared exclusively by Hwass, although the names and brief Latin diagnoses were. It is, however, the present author's opinion that Hwass's contribution is sufficient to justify attributing authorship of the names to him. This view is strengthened by the more recent further clarification of Article 21 (Copenhagen Decisions, 1953: 58–59), which states that "the rule set out on pages 565–566 of vol. 4 of the BULLETIN should be qualified in such a way as to make it clear that it applies only where the book or paper concerned contains a clear indication that not only the name in question was proposed by some author other than that by whom the book or paper was written but also that the indication, defini-

tion, or description on which, under Article 25, the availability of that name depends was written not by the author of the book or paper concerned but by the author to whom the name is there attributed."

For these reasons, the species of *Conus* referred to as, e.g. "*Conus catus* Hwass" in Bruguière (1792) are herein cited as, e.g. "*Conus catus* Hwass *in* Bruguière."

Museum Calonnianum. 1797. The names introduced in this publication were rejected in Opinion 51 of the ICZN (Smithsonian Publ. 2060, 1912: 116), but this decision has not been universally accepted. Of the names listed in the Museum Calonnianum, only three, all of which are synonyms, are pertinent to this paper. For the sake of completeness, they are listed in brackets in the synonymies. Authorship of the Museum Calonnianum is attributed to George Humphrey, following general acceptance. The problem is discussed in detail by Iredale (1937).

Museum Boltenianum. 1798. The names in this volume were accepted as nomenclatorially available in Opinion 96 of the ICZN (Smithsonian Misc. Coll., 73(4): 16–18, 1926), and their authorship was attributed to P. F. Röding in Direction 48 of the ICZN (Opinions and Declarations Rendered by the ICZN, 1: 255–264, 1956).

L. W. Dillwyn. *A Descriptive Catalogue of Recent Shells*. 1817. A number of species of *Conus* described by Chemnitz (1788, 1795) are listed in Dillwyn's catalogue. Since the specific names in Chemnitz (1788, 1795) have been rejected by Opinion 184 of the ICZN (Opinions and Declarations Rendered by the ICZN, 3: 27–35), these names became nomenclatorially available upon publication by Dillwyn (1817). (See also Bull. Zool. Nomencl., 4: 259–260, 1950.)

L. C. Kiener. *Spécies Général et Iconographie des Coquilles Vivantes*. 1845–1850. The names of species described in this work appear both on the plates and in the text. Hanna and Strong (1949) reproduce the summary of the collation of Sherborn and Woodward (1901: 218) which gives 1846 as the year of publication of the plates. This date, however, is erroneous, being presumably a typographical error. The correct date is 1845 as given in the body of the paper (Sherborn and Woodward, 1901: 217). Therefore, the names in Kiener's work should date from 1845 rather than from the dates on which they appeared in the text.[2]

Tomlin (1937) has given the most complete catalogue of the genus *Conus*. Some 2,700 names are listed, including both extant and fossil species. Earlier catalogues of Recent species are given by Reeve (1843–1849), Kiener (1845–1850), Sowerby (1857–1858), and Tryon (1884).

Earlier published lists of the species of *Conus* in Hawaii are those of Garrett (1878), Edmondson (1933, 1946), Tinker (1952, 1958), and Greene (1953). Extensive unpublished lists compiled by W. A. Bryan in 1919, and by E. H. Bryan, Jr. in 1956, have been made available to the writer by E. H. Bryan, Jr.

SYNONYMY

The synonymies consist of the first known publication of all known different names, authors, and combinations which have been applied to the species, listed chronologically. Subsequent references to the same name are not given, with the exception of errors and emendations, in order to conserve space. It is perhaps unfortunate that some of the references are to distributional lists and museum catalogues, which in many cases lack taxonomic information. These are included primarily because specific names first published in some of the museum catalogues have been recognized as available by the ICZN. Furthermore, in addition to their historical importance, such lists and catalogues are in some cases the source of errors which have been perpetuated in the subsequent literature.

Many specific names of *Conus* were introduced by authors who did not consistently use the binominal system. These names are

[2] The author is grateful to Dr. Harald A. Rehder for having pointed out this discrepancy.

thus invalid (see Opinions and Declarations Rendered by the ICZN, 3: 27–35; 5: 265–279) and have not been included in the synonymies. Among the post-Linnean authors responsible for such names are Martini (1773), Chemnitz (1788, 1795), Meuschen (1778, 1787), and Martyn (1784–1792).

In cases of generic changes by subsequent authors, the name of the author of the species has been placed in parentheses throughout, whether or not this was done by the author of the generic change.

Described varieties of listed valid species are not included in synonymies. However, if the listed valid species itself has been described as a variety of another species, that entry is included in the synonymy.

In cases of published erroneous identification of specimens, the notation "(error)" follows the entry.

Genus CONUS Linné

Shell obconical, turbinate; whorls enrolled upon themselves, attenuated anteriorly. Spire usually short, smooth or coronate. Aperture elongate, narrow, effuse at the base, without teeth; outer lip smooth, sharp, with a sutural sinus.

Conus abbreviatus Reeve

Fig. 33 in Plate 2

Conus abbreviatus Reeve, 1843, Conch. Icon., 1: pl. 16, sp. 86.

Conus abbreviatus Sowerby, 1857, Thes. Conchyl., 3: 10 (as "*C. abbreviatus* Nuttall MS., Reeve C.I." on pl. 4, fig. 84).

Conus coronatus Dillwyn var. *abbreviatus*. Weinkauff, 1874, Jahrb. Deutsch. Malak. Ges., 1: 250.

Conus miliaris Hwass var. *abbreviatus*. Tryon, 1884, Man. Conch., 1: 22, pl. 5, fig. 89.

Stephanoconus abbreviatus (Reeve). Kaicher, 1956, Indo-Pacific Sea Shells, Sect. 5, pl. 2, fig. 4.

DESCRIPTION: Shell small but sturdy. Body whorl striate, the striae as raised ridges near the base, impressed and widely spaced elsewhere. Aperture fairly narrow, flaring somewhat towards the anterior, or basal end. Base attenuated. Shoulder coronate; spire depressed, coronate, striate. Color bluish gray, with pale flesh-colored transverse bands in the middle of the body whorl and at the shoulder; with rows of rather distantly spaced small brown dots encircling the body whorl. Aperture purplish brown within, with a light median band. Periostracum thin, yellow, translucent. In life, foot pale brown; siphon pale brown, tinged with pink.

LENGTH: To 60 mm., but usually smaller.

TYPE LOCALITY: Oahu.

REMARKS: It is believed that this species is endemic to the Hawaiian archipelago. It is known from Midway Island and all of the main islands, where it is usually rather common on marine benches. Larger specimens are found on sandy substrata of coral reef platforms.

Conus miliaris Hwass and *C. coronatus* Gmelin, neither of which occurs in Hawaii, are the most closely related species. *C. abbreviatus* may be distinguished from both by the regular arrangement and small size of the brown dots, by the characteristic bluish-gray ground color, and by the absence of irregular longitudinal white flecks (as in *C. miliaris*) or brown blotches (as in *C. coronatus*).

Pleistocene fossils of *C. abbreviatus* are known from Oahu (Ostergaard, 1928), Maui, and Molokai (Ostergaard, 1939).

Conus acutangulus Lamarck

Fig. 37 in Plate 2

Conus acutangulus Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 286.

Leptoconus acutangulus. Adams and Adams, 1853, Gen. Rec. Moll., 1: 251.

Conus acutangulatus Sowerby, 1857, Thes. Conchyl., 3: 11.

(?) *Conus crebrisulcus* Sowerby, 1857, Thes. Conchyl., 3: 21, pl. 14, fig. 321.

Conus turriculatus Sowerby, 1866, Thes. Conchyl., 3: 328, pl. 27, figs. 643, 644.
Conus gemmulatus Sowerby, 1870, Proc. Zool. Soc. Lond., 1870: 257, pl. 22, fig. 8.
Conus acutangulus Bruguière. Paetel, 1883, Catal. Conch.-Samml. Paetel, p. 50.
Conus acutangulus Hwass. Tryon, 1884, Man. Conch., 6: 76.
Conus acutanculus Friedberg, 1911, Rozprawyi Wiadomości Muzeum Imienia Dzieduszyckich (Moll. Mioc. Poloniae), 14: 47.
Conus eugrammatus Bartsch and Rehder, 1943, Proc. Biol. Soc. Wash., 56: 85.
Conasprella acutangulus (Lamarck). Cotton, 1945, Rec. South Austral. Mus., 8: 272.
Conus eugrammatus Dall, Bartsch and Rehder. Greene, 1953, Ann. Rept. Amer. Malacol. Union, Bull. 20: 28.
Asprella acutangulus (Lamarck). Kuroda, 1956, Venus: Jap. Jour. Mal., 19: 88.

DESCRIPTION: Shell small, rather thin. Body whorl elongate, bearing rather distantly and irregularly spaced incised spiral lines marked by small punctures. Aperture narrow, outer lip protracted. Shoulder angular, ridged; spire elevated, turreted, concave, striate, comprising at least one third of the total shell length; apex sharp. Early whorls smooth, succeeding whorls with slender protracting curved axial riblets which fuse to form strong nodules at the shoulder, the nodules becoming less conspicuous on the latest whorls. Color of body whorl white to pale buff, marked with interrupted broad brown spiral bands either side of the center. Rows of brown dots between the striae mark the light area between the brown bands. Spire marked by distantly spaced rather regular broad brown spots. Periostracum grayish white, bearing lamellae on the fine riblets of the spire.

LENGTH: 30 mm.

TYPE LOCALITY: "Mers des grandes Indes."

REMARKS: Specimens of *C. acutangulus* have been collected in Hawaii by dredging in comparative shallow water and to a depth of 200 fathoms.

Conus bullatus Linné

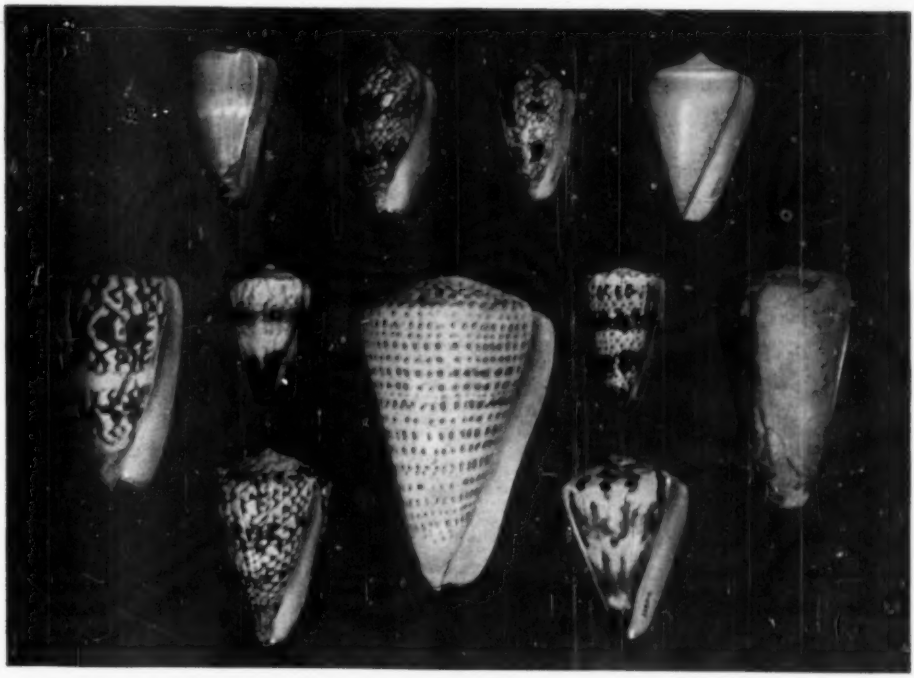
Fig. 1

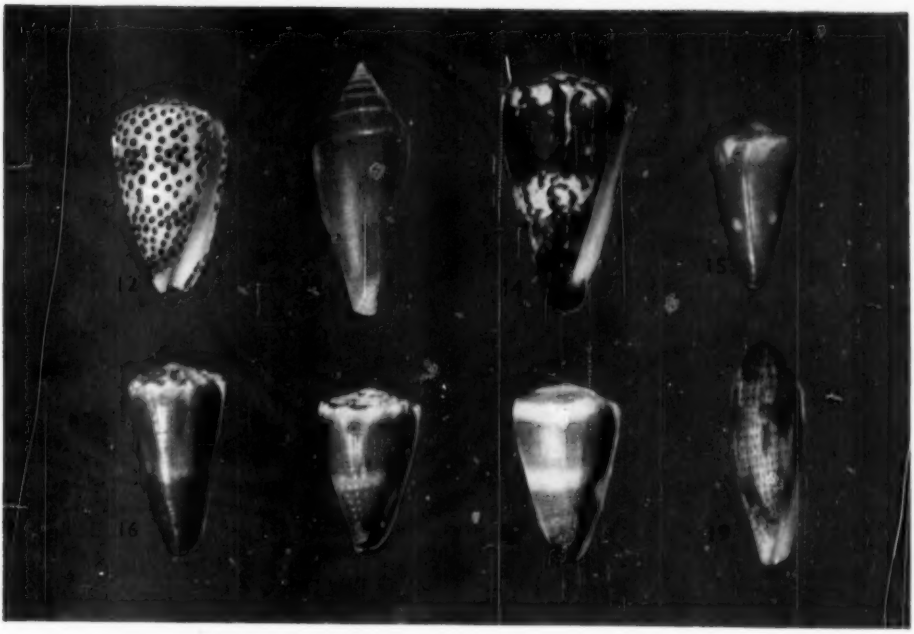
Conus bullatus Linné, 1758, Syst. Nat., ed. 10, p. 717.

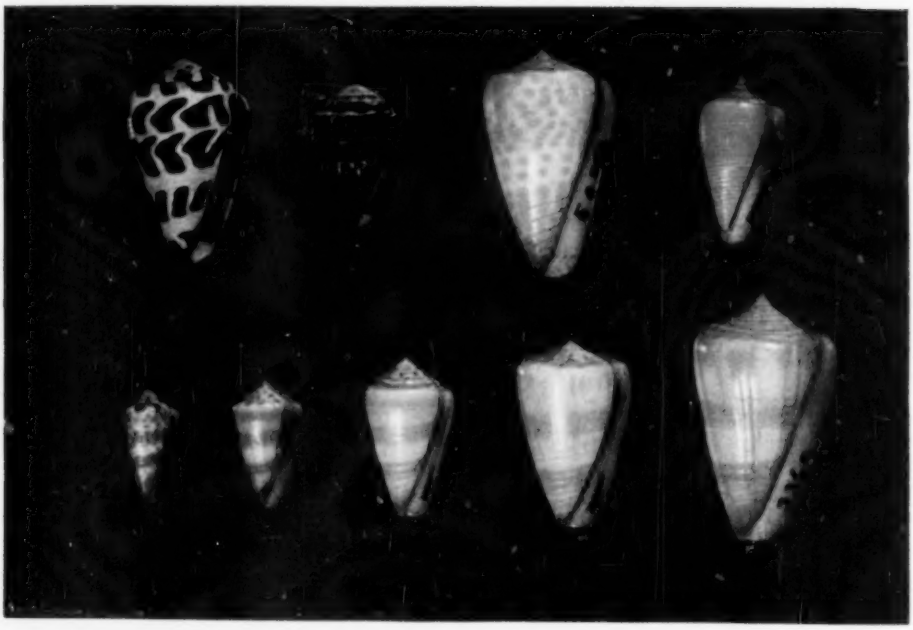
PLATE 1

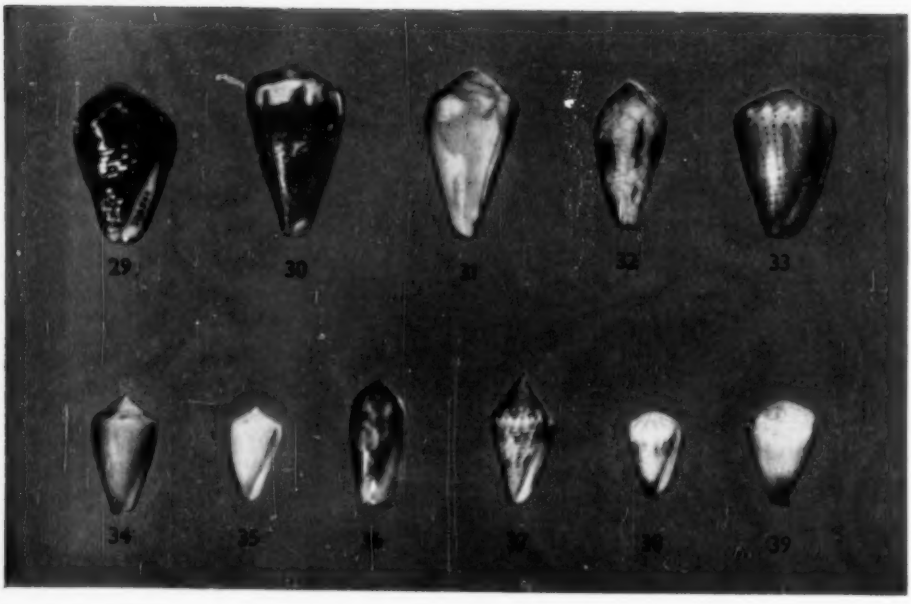
References are given to the shells figured. The dimensions given are shell length × maximum diameter.

FIG. 1. *Conus distans* Hwass *in* Bruguière. 75 × 43 mm. Off Rabbit (Manana) Island, off Oahu. USNM coll., No. 484738.
FIG. 2. *Conus textile* Linné. 80 × 44 mm. Waikiki, Oahu. C. E. Cutress coll.
FIG. 3. *Conus pennaceus* Born. 64 × 35 mm. Keaukaha, Hilo, Hawaii. USNM coll., No. 338584.
FIG. 4. *Conus quercinus* Solander. 80 × 49 mm. Honolulu Harbor Channel, Oahu. USNM coll., No. 338584.
FIG. 5. *Conus striatus* Linné. 107 × 53 mm. Waikiki, Oahu. C. E. Cutress coll.
FIG. 6. *Conus miles* Linné. 67 × 39 mm. Waikiki, Oahu. C. E. Cutress coll.
FIG. 7. *Conus imperialis* Linné. 69 × 36 mm. Lahaina, Maui. USNM coll., No. 484735.
FIG. 8. *Conus spiceri* Bartsch & Rehder. 113 × 62 mm. Midway Island. USNM coll., No. 523700.
FIG. 9. *Conus marmoreus* Linné. 96 × 54 mm. Honolulu Harbor entrance, Oahu, 5–8 fathoms. USNM coll. No. 338163.
FIG. 10. *Conus leopardus* (Röding). 143 × 86 mm. Waimea Bay, Oahu. C. E. Cutress coll.
FIG. 11. *Conus vexillum* Gmelin. 88 × 54 mm. Kahala, Oahu. USNM coll., No. 338510.
FIG. 12. *Conus pulicarius* Hwass *in* Bruguière. 48 × 27 mm. Honolulu, Oahu. USNM coll., No. 338195.
FIG. 13. *Conus smirna* Bartsch & Rehder. Holotype. 61 × 23 mm. off Lanai, 257–312 fathoms. USNM coll., No. 173226.
FIG. 14. *Conus vitulinus* Hwass *in* Bruguière. 56 × 31 mm. Keokea, Hawaii. USNM coll., No. 338549.
FIG. 15. *Conus litoglyphus* Hwass *in* Bruguière. 41 × 19 mm. Honolulu Harbor entrance, Oahu, 5–8 fathoms. USNM coll., No. 338538.
FIG. 16. *Conus moreleti* Crosse. 46 × 23 mm. Kailua, Oahu, 12–15 feet. USNM coll., No. 484249.
FIG. 17. *Conus lividus* Hwass *in* Bruguière. 39 × 23 mm. Honokowai, Maui. USNM coll., No. 338531.
FIG. 18. *Conus flavidus* Lamarck. 42 × 25 mm. Honokowai, Maui. USNM coll., No. 338522.
FIG. 19. *Conus nussatella* Linné. 53 × 17 mm. Kuhio Bay, Hilo, Hawaii. USNM coll., No. 338577.





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Conus nubecula Gmelin, 1791, Syst. Nat., ed. 13, p. 3396.
Cucullus nubecula (Gmelin). Röding, 1798, Mus. Boltenianum, p. 46.
Cucullus parvus Röding, 1798, Mus. Boltenianum, p. 46.
Cucullus laganum Röding, 1798, Mus. Boltenianum, p. 51.
Conus bullatus Lamarck. Sowerby, 1833, Conch. Illus., p. 2, pt. 29, fig. 23.
Textilia bullatus. Swainson, 1840, Treat. Mal., p. 312.
Leptoconus bullatus (Linné). Adams and Adams, 1853, Gen. Rec. Moll., 1: 253.
Textilia bullata (Linné). Cotton, 1945, Rec. South Austral. Mus., 8: 261.

DESCRIPTION: Shell rather thick but not heavy, ovate-oblong, the maximum diameter not at the shoulder but about one third of the distance from shoulder to base. Body whorl glossy, with impressed, rather widely spaced transverse striae basally. Shoulder rounded, smooth; spire obsoletely striate, canaliculate. Ground color white or pale pink, clouded with orange brown subtrigonal markings often fused to form three broad, rather poorly defined transverse bands, separated by areas of sparser, irregularly placed similar markings. Spire marked irregularly with orange brown and pink or pinkish white. Interior of aperture pinkish orange. Periostracum thin.

LENGTH: The most recently collected specimen from Hawaii (see below) measures 62 × 29 mm.

TYPE LOCALITY: None.

REMARKS: Very few specimens of *Conus bullatus* are known from the Hawaiian Islands. A single shell in excellent condition was dredged off Nanakuli, Oahu, but whether or not it was alive is not known (D. Thaanum, *in litt.*). In November, 1957, a living specimen (Fig. 1) was collected half-buried in sand at a depth of 100 feet off Diamond Head, Oahu (C. S. Weaver, *in litt.*). At least two other specimens are believed to have been collected in Hawaii, but it has not been possible to verify the reports. In addition, a number of dead shells have been collected (K. W. Greene, *in litt.*; L. Brand, verbal communication).

Conus capitaneus Linné

Fig. 2

Conus capitaneus Linné, 1758, Syst. Nat., ed. 10, p. 713.

PLATE 2

References are given to the shells figured. The dimensions given are shell length × maximum diameter.

FIG. 20. *Conus ebraeus* Linné. 39 × 23 mm. Hilo, Hawaii. USNM coll., No. 338209.

FIG. 21. *Conus chaldaeus* (Röding). 29 × 18 mm. Hilo, Hawaii. USNM coll., No. 338477.

FIG. 22. *Conus tessulatus* Born. 42 × 25 mm. "Sandwich Is." USNM coll., No. 5038. A faded specimen.

FIG. 23. *Conus quercinus* Solander. 33 × 16 mm. Off Kaanapali, Maui, 4–12 fathoms. USNM coll., No. 338187. Juvenile specimen, showing the characteristic high spire.

FIGS. 24–28. *Conus suturatus* Reeve, showing changes in color pattern with increase in size. FIG. 24. 23 × 11 mm. Off Launiupoko Camp, Maui, 4–12 fathoms. USNM coll., No. 338546. FIG. 25. 25 × 13 mm. Off Mt. Lihau, Maui, 4–12 fathoms. USNM coll., No. 338547. FIG. 26. 32 × 17 mm. USNM coll., No. 338546. FIG. 27. 37 × 21 mm. Honolulu Harbor entrance, Oahu, 5–8 fathoms. USNM coll., No. 338541. FIG. 28. 48 × 27 mm. North Island, Pearl and Hermes Reef. Mrs. J. Bromley coll., No. 3363.

FIG. 29. *Conus catus* Hwass *in* Bruguière. 29 × 18 mm. Honokowai, Maui. USNM coll., No. 338561.

FIG. 30. *Conus rattus* Hwass *in* Bruguière. 30 × 17 mm. Honolulu, Oahu. USNM coll., No. 338516.

FIG. 31. *Conus pertusus* Hwass *in* Bruguière. 30 × 15 mm. Locality unknown. USNM coll., No. 18522.

FIG. 32. *Conus retifer* Menke. Midway Island. USNM coll., No. 524591. A faded specimen.

FIG. 33. *Conus abbreviatus* Reeve. 26 × 17 mm. Honokowai, Maui. USNM coll., No. 338488.

FIG. 34. *Conus circumactis* Iredale. 22 × 11 mm. Off Lanai, 179–253 fathoms. (Holotype of *Conus h mmatus* Bartsch and Rehder). USNM coll., No. 173225. Juvenile.

FIG. 35. *Conus circumactis* Iredale. 17 × 9 mm. USNM coll. Juvenile.

FIG. 36. *Conus obscurus* Sowerby. 23 × 9 mm. Off Waikiki, Oahu, 20 feet. USNM coll., No. 484740.

FIG. 37. *Conus acutangulus* Lamarck. 24 × 10 mm. Honolulu Harbor entrance, Oahu, 6–8 fathoms. USNM coll., No. 338564.

FIGS. 38–39. *Conus sponsalis* Hwass *in* Bruguière. Kauai. USNM coll. FIG. 38. 15 × 9 mm. FIG. 39. 18 × 11 mm.

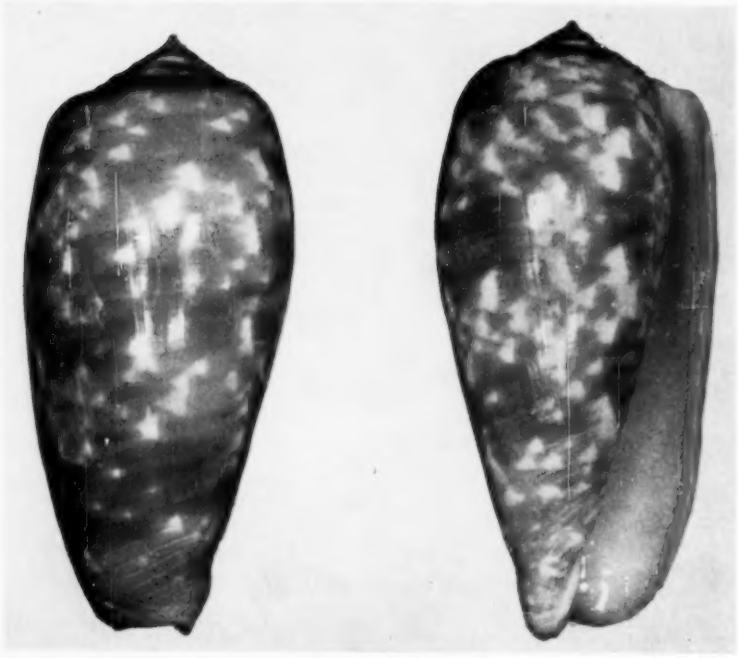

FIG. 1. *Conus bullatus* Linné, 62 × 29 mm. Collected off Diamond Head, Oahu, 17 fathoms. Shell in collection of C. S. Weaver. Photographs by the author.

Conus classiarius Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 705, pl. 335, fig. 7.
[*Conus venator* Humphrey, 1797, Mus. Calonnianum, p. 11.]
[*Conus agasus* Humphrey, 1797, Mus. Calonnianum, p. 11.]
Cucullus capitaneus (Gmelin). Röding, 1798, Mus. Boltenianum, p. 43.
Conus classiarius Bruguière. Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 267.
Conus chemnit . Dillwyn, 1817, Descr. Cat. Rec. Shells, 1: 363.
Conus capitaneus Lamarck. Dufo, 1840, Ann. Sci. Nat., Ser. 2, 14: 172.
Leptoconus capitaneus (Linné). Adams and Adams, 1853, Gen. Rec. Moll., 1: 252.
Conus ceciliae Crosse, 1858, Jour. Conchyl., 7: 381, pl. 14, fig. 5.
Rhizoconus capitaneus (Linné). Frauenfeld, 1869, Verh. Zool.-Bot. Ges. Wien, 19: 863.
Conus chemnitzi Dillwyn. Dautzenberg, 1937, Mem. Mus. Roy. Hist. Nat. Belg., 2(18): 171.
Lithoconus capitaneus (Linné). Kaicher, 1956, Indo-Pacific Sea Shells, Sect. 5, pl. 4, fig. 9.

DESCRIPTION: Shell of moderate thickness; body whorl encircled by finely punctate striae on the basal half, the striae more distinct and separated by low ridges basally; aperture rather narrow, the sides parallel. Shoulder angular, smooth; spire rather low, obtuse, striate; apex pointed. Color of body whorl variable, yellow or olive yellow to orange brown or olive brown, encircled by several dark brown dotted lines and two broad white bands, interrupted by dark brown blotches, at the shoulder and centrally on the body whorl. The white bands may also be crossed by closely spaced longitudinal wavy brown

lines. Young individuals may lack the two white bands. Spire tesselated with alternate brown and white blotches, continuing to form band on body whorl at shoulder. Outer lip thin; aperture violet within. Periostracum rather thin but opaque, encircled by raised transverse ridges.

LENGTH: The only two specimens known from the Hawaiian Islands (Fig. 2) measure 31 × 21 mm. and 19.5 × 11.5 mm.

TYPE LOCALITY: Asia.

REMARKS: This species was not known to occur in the Hawaiian area until the collection of a living specimen (Fig. 2, right) by Mrs. A. M. Harrison at a depth of 15–20 feet off Nanakuli, Oahu, in April, 1958. A second, smaller specimen (Fig. 2, left) was collected by Mr. A. M. Harrison at a depth of 35 feet near Kaena Pt., Oahu, on 31 August 1958.

Conus catus Hwass *in* Bruguière

Fig. 29 in Plate 2

Conus catus Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 707, pl. 332, figs. 3, 4, 7.
Conus leoninus var. δ Gmelin, 1791, Syst. Nat., ed. 13, p. 3387.
Cucullus nubilus Röding, 1798, Mus. Boltenianum, p. 46.
Conus nubilus (Bolten). Link, 1807, Beschreib. Nat.-Samml. Univ. Rostock, Abt. 3, p. 105.
Conus catus Bruguière. Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 285.
Conus discrepans Sowerby, 1833, Conch. Illus., p. 2, pt. 29, fig. 28.
Conus catus Lamarck. Dufo, 1840, Ann. Sci. Nat., Ser. 2, 14: 173.
Leptoconus catus (Hwass). Adams and Adams, 1853, Gen. Rec. Moll., 1: 253.
(?) *Conus purus* Pease, 1862, Proc. Zool. Soc. Lond., p. 279.
Chelyconus catus (Bruguière). Cotton, 1945, Rec. South Austral. Mus., 8: 241.
Chelyconus catus (Hwass). Kaicher, 1956, Indo-Pacific Sea Shells, Sect. 5, pl. 6, fig. 10.

DESCRIPTION: Shell stout, solid, bulbous. Body whorl striate, the striae raised, rounded, usually obsolete near the shoulder, and granular near the base. Aperture rather broad, the sides almost parallel. Shoulder rounded, smooth; spire obtuse, deeply striate. Apex sharp, rose-colored, but often eroded. Color of body whorl and spire brown with irregular white flecks or splotches. Aperture white with brown margin. Periostracum thin, yellow, translucent. In life, foot mottled brown on buff. "Pale cinereous, varied with delicate brown mottlings, which are most conspicuous on the muzzle" (Garrett, 1878).

LENGTH: To 40 mm.

TYPE LOCALITY: Several localities are given with the original description, the first two of which, "Saint-Domingue" and Martinique, are almost certainly in error. The species described as *Conus catus* is restricted to the Indo-West Pacific region although it resembles *Conus ranunculus* Hwass *in* Bruguière, a western Atlantic species.

REMARKS: *Conus catus* is less variable with respect to shell characteristics in Hawaii than in other parts of the Pacific and Indian oceans. It occurs intertidally on benches and rocky shores and subtidally as well. Pleistocene fossils are known from Oahu (Ostergaard, 1928).

Conus chaldaeus (Röding)

Fig. 21 in Plate 2

Conus princeps Linné. Born, 1778, Ind. Rer. Nat. Mus. Caes. Vind., p. 134. (error).
Conus princeps var. β. Gmelin, 1791, Syst. Nat., ed. 13, p. 3378.
Conus ebraeus Linné var. E. Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 619, pl. 321, figs. 1, 7, 8.
Cucullus chaldaeus Röding, 1798, Mus. Boltenianum, p. 42.
Conus chaldaeus (Bolten). Link, 1807, Beschreib. Nat.-Samml. Univ. Rostock, Abt. 3, p. 106.

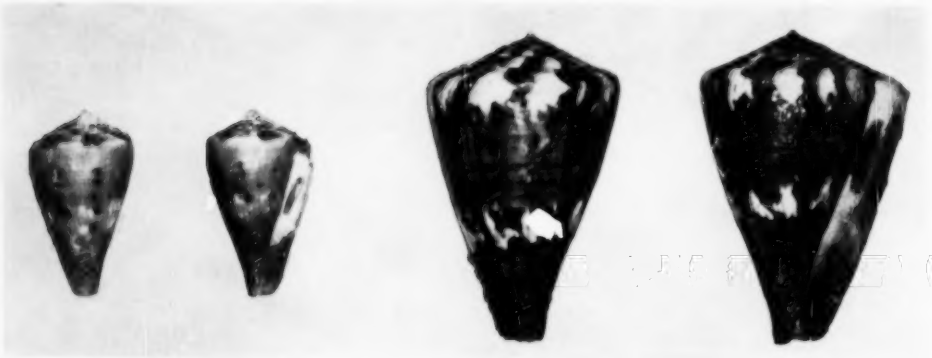

FIG. 2. *Conus capitaneus* Linné. Left, 19.5 × 11.5 mm. Specimen collected by A. M. Harrison near Kaena Pt., Oahu, 6 fathoms. Right, 31 × 21 mm. Specimen collected by Mrs. A. M. Harrison near Nanakuli, Oahu, 3 fathoms. Photographs by the author.

Conus vermiculatus Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 34.

Conus ebraeus Linné var. C. Dillwyn, 1817, Descr. Cat. Rec. Shells, p. 399.

Conus ebraeus Linné var. D. Dillwyn, 1817, Descr. Cat. Rec. Shells, p. 399.

Conus hebraeus Linné var. *β*. Reeve, 1843, Conchol. Icon., 1: pl. 19, fig. 104a.

Conus hebraeus Linné var. *vermiculatus* Lamarck. Kiener, 1846, Spéc. Gén. Icon. Coq. Viv., 2: 46, pl. 8, fig. 3.

Conus ebraeus Linné var. *vermiculatus* Hwass. Weinkauff, 1874, Jahrb. Deutsch. Malak. Ges., 1: 249.

Conus ebraeus Linné var. *vermiculatus* Lamarck: Crosse and Marie, 1874, Jour. Conchyl., 22: 340.

Conus hebraeus Linné var. *vermiculatus* Hwass. Kobelt, 1878, Illus. Conchyl., p. 92.

Conus vermiculatus Bruguière. Fischer, 1891, Bull. Soc. Hist. Nat. Autun, 4: 132.

Conus ebraeus Linné var. *vermiculata* Lamarck. Couturier, 1907, Jour. Conchyl., 55: 126.

Cucullus chaldaeus Bolten. Iredale, 1929, Mem. Queensl. Mus., 9: 282.

Virroconus chaldaeus (Bolten). Cotton, 1945, Rec. Austral. Mus., 8: 236.

Conus chaldeus (Röding). Tinker, 1952, Pacific Sea Shells, p. 44.

Conus chaldens (Röding). Dietrich and Morris, 1953, Nautilus, 67: 17, pl. 4, fig. 19.

Virroconus chaldeus (Röding). Kira, 1955, Coloured Illus. Shells Japan, p. 72.

Stephanoconus chaldeus (Röding). Kaicher, 1956, Indo-Pacific Sea Shells, Sect. 5, pl. 2, fig. 10.

Conus ebraeus chaldaeus Röding. Hertlein and Emerson, 1957, Amer. Mus. Novit., No. 1859: 3.

DESCRIPTION: Shell rather small but extremely thick and sturdy. Body whorl transversely striate, the striae obsoletely tuberculate near the base, becoming strongly so near the shoulder; aperture narrow. Shoulder coronate; spire moderately elevated, tuberculate, striate; apex often eroded. Color mostly black, with narrow, irregular, usually interrupted white bands at the shoulder and centrally on the body whorl, the black areas also interrupted by intermittent vertical white streaks. Aperture bluish white, the external color pattern visible at the outer lip. Periostracum rather thin, yellow, translucent. In life, foot black, with a broad central longitudinal tan stripe on the sole. Siphon and rostrum black, tipped with red.

LENGTH: Usually less than 40 mm. A specimen collected by the author at Waikiki, Oahu, measures 44 mm.

TYPE LOCALITY: None.

REMARKS: This species is closely related to *Conus ebraeus* and is regarded as a variety of that species by some recent workers (e.g. Dodge, 1953). It differs from *C. ebraeus* in being generally smaller, having a tuberculate surface, and having the black flammules confluent so as to cover most of the shell. The two species are sympatric over a wide range. Hawaiian specimens are easily distinguishable. In other areas, the two species tend to approach each other more closely morphologically but do not intergrade. Lamarck's (1810) statement that the two species are constantly distinct is correct.

C. chaldaeus occurs most commonly near the outer edge of marine benches. Pleistocene fossils are known from Oahu (Ostergaard, 1928).

Conus circumactis Iredale

Figs. 34 and 35 in Plate 2; Fig. 3

Conus cinctus Swainson, 1822, Zool. Illus., ser. 1, 2: pl. 110. (non *cinctus* Bosc, 1801.)

Conus pulchellus Swainson, 1822, Zool. Illus., ser. 1, 2: pl. 114. (non *pulchellus* Röding, 1798.)

Rhizoconus pulchellus (Swainson). Adams and Adams, 1853, Gen. Rec. Moll., 1: 252.

(?) *Conus connectens* A. Adams, 1854, Proc. Zool. Soc. Lond., 1854: 136.

Conus circumactis Iredale, 1929, Mem. Queensl. Mus., 9: 281.

Conus hammatus Bartsch and Rehder, 1943, Proc. Biol. Soc. Wash., 56: 86.

Dauciconus circumactis (Iredale). Cotton, 1945, Rec. South Austral. Mus., 8: 246.

Conus hammatus Dall, Bartsch and Rehder. Greene, 1953, Ann. Rept. Amer. Malacol. Union, Bull. 20: 28.

Leptoconus circumactis (Iredale). Kuroda, 1956, Venus: Jap. Jour. Mal., 19: 73.

DESCRIPTION: Shell rather thin; body whorl slightly concave near the base on the left side, spirally striate with the striae obsolete and impressed toward the shoulder but stronger and with widely spaced low knobs basally. Aperture narrow, widening slightly basally; outer lip thin. Shoulder angular, smooth or

FIG. 3. *Conus circumactis* Iredale. Specimens dredged by C. A. Allen off southern shore of Oahu, 8–60 fathoms Left, 21 × 12 mm.; center, 25 × 13 mm.; right, 34 × 18 mm. Photographs by M. Miyamoto.

extremely obsoletely coronate. Spire low; apex nipplelike, especially in young specimens; whorls finely striate, separated by a deeply impressed suture. Color of body whorl pale yellow or yellowish brown, with large white blotches forming a band at the shoulder and another at the middle; body whorl also encircled by narrow brown lines, which are usually interrupted to form dots and dashes; base violet or pink; interior of aperture bluish or pinkish white. Spire white or pinkish white, sparsely maculated with brown. Periostracum rather thick, yellowish brown and opaque in young specimens, yellow and somewhat translucent in older individuals.

LENGTH: 35 mm.

TYPE LOCALITY: Amboina.

REMARKS: All specimens of *C. circumactis* known from the Hawaiian Islands have been collected by dredging. The holotype of *C. hammatus* Bartsch and Rehder, here considered the juvenile of *C. circumactis*, was dredged off Kauai in about 200 fathoms. C. A. Allen collected thirteen specimens from depths of 8–60 fathoms off the southern shore of Oahu.

Of the other species of *Conus* in Hawaii, *C. vitulinus* is most closely related to *C. circumactis*. The latter can be distinguished by its pale ground color, pink or violet base, and yellowish brown periostracum. *C. circumactis* can be distinguished from *C. litoglyphus* by the narrow interrupted transverse brown lines and the pink or violet base in the former.

Conus distans Hwass *in* Bruguière

Fig. 1 in Plate 1

Conus distans Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 634, pl. 321, fig. 11.

Conus distans Bruguière. Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 38.

Virroconus distans (Bruguière). Cotton, 1945, Rec. South Austral. Mus., 8: 254.

Rhizoconus distans (Bruguière). Kira, 1955, Coloured Illus. Shells Japan, p. 75.

Virgiconus distans (Bruguière). Kuroda, 1955, Venus: Jap. Jour. Mal., 18: 291.

Stephanoconus distans (Hwass). Kaicher, 1956, Indo-Pacific Sea Shells, Sect. 5, pl. 2, fig. 16.

DESCRIPTION: Shell large, elongate, slightly concave in profile. Body whorl smooth or encircled with obsolete impressed lines; aperture narrow, the sides parallel. Shoulder coronate; spire short, coronated with obtuse rounded tubercles. Color of body whorl yellowish tan, obsoletely banded with white or pale bluish white at the center and near the shoulder. Tubercles of the spire white, depressed areas between them dark brown. A purplish brown stain usually present near the base. Interior of aperture light violet with a lighter central band, darker violet at the base. The violet of the interior is deeper in juvenile specimens, which are generally more colorful. Periostracum thick, olive green, with transverse rows of tufted ridges on body whorl. In life, foot brown; siphon light tan, mottled with brown; rostrum dark brown, tipped with yellow; tentacles light brown; penis orange.

LENGTH: 120 mm.

TYPE LOCALITY: New Zealand. In error (see Wilkins, 1955: 106).

REMARKS: *C. distans* occurs chiefly at the outer areas of reef platforms and in depths of one or more fathoms.

Conus ebraeus Linné

Fig. 20 in Plate 2

Conus ebraeus Linné, 1758, Syst. Nat., ed. 10, p. 715.

Conus hebraeus Linné. Born, 1778, Ind. Rer. Nat. Mus. Caes. Vind., p. 142.

Cucullus ebraeus (Gmelin). Röding, 1798, Mus. Boltenianum, p. 42.

Conus quadratus Perry, 1811, Conchology, pl. 24, fig. 5. (non *quadratus* Röding, 1798.)

Conus hebraeus Hwass. Blainville, 1818, Dict. Sci. Nat., 10: 249.

Conus hebraeus Lamarck. Dufo, 1840, Ann. Sci. Nat., Ser. 2, 14: 170.

Conus hebreus. Montrouzier, 1856, Ann. Soc. Imp. Agr. Lyon, 8: 416.

Coronaxis hebraeus (Linné). Frauenfeld, 1869, Verh. Zool.-Bot. Ges. Wien, 19: 863.
Virroconus ebraeus (Linné). Iredale, 1930, Mem. Queensl. Mus., 10: 80.
Stephanoconus ebraeus (Linné). Kaicher, 1956, Indo-Pacific Sea Shells, Sect. 5, pl. 2, fig. 9.

DESCRIPTION: Shell solid; body whorl smooth, becoming encircled with obsolete raised ridges toward the base; outer lip of aperture flaring slightly basally. Shoulder coronate, often obsoletely so; spire of moderate height, often somewhat eroded, indistinctly coronate. Color white with usually three rows of large angular rhomboidal black flammules, with another row encircling the shoulder. Aperture with clouded bands corresponding with the exterior markings. Periostracum thin, yellow, translucent. In life, foot black, with a broad longitudinal central buff stripe on the sole. Siphon and rostrum black, tipped with a narrow red margin.

LENGTH: This species attains greater length in the Hawaiian Islands than in other parts of its extensive range. Specimens exceeding 50 mm. are often found. A specimen collected by the author at Diamond Head, Oahu, measures 56 mm. in length.

TYPE LOCALITY: India.

REMARKS: One of the most abundant species of *Conus* in the Hawaiian Islands, *C. ebraeus* is the dominant species on intertidal benches and occurs also on reef platforms. Pleistocene fossils are known from Oahu (Ostergaard, 1928).

Conus flavidus Lamarck

Fig. 18 in Plate 1

Conus flavidus Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 265.
Conus virgo Linné var. Dillwyn, 1817, Descr. Cat. Rec. Shells, 1: 362.
Dendroconus flavidus (Lamarck). Adams and Adams, 1853, Gen. Rec. Moll., 1: 250.
Conus neglectus Pease, 1860, Proc. Zool. Soc. Lond., pt. 28: 398. (non *neglectus* A. Adams, 1853.)
Conus flavidus Bruguière. Issel, 1869, Malacologia del Mar Rosso, p. 143.
Lithoconus flavidus (Lamarck). Brazier, 1877, Proc. Linn. Soc. New South Wales, 1: 288.
Lithoconus peasei Brazier, 1877, Proc. Linn. Soc. New South Wales, 1: 288.
Conus lividus Hwass var. *flavidus* Lamarck. Smith, 1879, Phil. Trans. Roy. Soc. Lond., 168 (extra volume): 477.
Virgiconus flavidus (Lamarck). Cotton, 1945, Rec. South Austral. Mus., 8: 254.

DESCRIPTION: Shell thick and heavy. Body whorl transversely striate, the striae more pronounced and raised toward the base; aperture narrow. Shoulder rather square, smooth; spire low, striate. Color of body whorl usually olivaceous or yellowish brown banded with white and/or bluish white at the shoulder and below the middle. Base stained dark violet. Aperture violet, with a light central band and yellow margin. Periostracum gray, transversely ridged in young specimens, smooth in older individuals. In life, upper surface of foot reddish brown, mottled with brown; remainder of foot and rostrum light yellowish brown mottled with darker brown; tip of siphon yellow, followed proximally by black and yellow bands; remainder of siphon yellow mottled with black. Tentacles white to yellow.

LENGTH: 50 mm.

TYPE LOCALITY: None.

REMARKS: *C. flavidus* is one of the commonest species of *Conus* on Hawaiian coral reefs. Pleistocene fossils have been collected on Oahu by Ostergaard (1928) and the writer and on Molokai by Ostergaard (1939).

Conus imperialis Linné

Fig. 7 in Plate 1

Conus imperialis Linné, 1758, Syst. Nat., ed. 10, p. 712.
Conus fuscatus Born, 1778, Ind. Rer. Nat. Mus. Caes. Vind., p. 126.
Cucullus imperialis (Gmelin). Röding, 1798, Mus. Boltenianum, p. 37.

Cucullus corona-ducalis Röding, 1798, Mus. Boltenianum, p. 38.
Cucullus regius Röding, 1798, Mus. Boltenianum, p. 38. (non *regius* Gmelin, 1791.)
Conus viridulus Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 31.
Conus imperialis Lamarck. Sowerby, 1839, Conch. Illus., p. 4, pt. 157–158, figs. 128, 129.
Conus fuscatus Lamarck. Sowerby, 1839, Conch. Illus., p. 4, pt. 157–158, figs. 130, 131.
Conus viridulus Linné. Adams and Adams, 1853, Gen. Rec. Moll., 1: 247.
Conus queketti Smith, 1906, Ann. Natal Govt. Mus., 1: 22, pl. 7, fig. 1.
Cucullus imperialis (Linné). Kira, 1955, Coloured Illus. Shells Japan, p. 72.
Rhombus imperialis (Linné). Kuroda, 1955, Venus: Jap. Jour. Mal., 18: 289.

DESCRIPTION: Shell large and sturdy, body whorl elongate, striate basally; outer lip thin. Shoulder coronate; spire low, strongly coronate. Ground color of shell white, with numerous interrupted light and dark brown bands on the spire as well as on the body whorl. Two broad yellowish brown bands encircle the body whorl. The band nearer the shoulder is broader. Both bands contain several narrow revolving dark brown lines interrupted by white. Color of base pale blue, often as narrow interrupted revolving lines. Base of aperture stained with a dark purple marginal band. Periostracum thin, yellow, translucent, but often obscured by epizooic coralline algae in nature. In life, exposed soft parts red, speckled with black.

LENGTH: 90 mm.

TYPE LOCALITY: None.

REMARKS: *C. imperialis* occurs on reef platforms and to a depth of at least 30 fathoms. Pleistocene fossils are known from Oahu (Ostergaard, 1928).

Conus leopardus (Röding)

Fig. 10 in Plate 1

(?) *Conus litteratus* Linné var. β Born, 1778, Ind. Rer. Nat. Mus. Caes. Vind., p. 128.
Conus litteratus Linné var. β Born, 1780, Test. Mus. Caes. Vind., p. 149.
Conus litteratus Linné var. D Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 638, pl. 324, fig. 4.
Conus litteratus Linné var. G Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 638, pl. 324, fig. 3.
Conus litteratus Linné var. I Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 638, pl. 323, fig. 5.
Cucullus leopardus Röding, 1798, Mus. Boltenianum, p. 41.
Conus literatus var. B. Dillwyn, 1817, Descr. Cat. Rec. Shells, 1: 357.
Conus millepunctatus Lamarck, 1822, Hist. Nat. Anim. sans Vert., 7: 461. (non *millepunctatus* Röding, 1798.)
Conus litteratus Linné var. *millepunctatus* Lamarck. Anton, 1839, Verzeichniss, p. 105.
Conus mille punctatus Lamarck. Dufo, 1840, Ann. Sci. Nat., Ser. 2, 14: 167.
Conus millepunctatus Linné. Mörch, 1852, Catal. Conchyl. Yoldi, p. 66.
Dendroconus millepunctatus (Lamarck). Adams and Adams, 1853, Gen. Rec. Moll., 1: 250.
(?) *Leptoconus leopardus*. Adams and Adams, 1853, Gen. Rec. Moll., 1: 252.
Conus millepunctatus Bruguière. Sowerby, 1857, Thes. Conchyl., 3: 23, pl. 7, fig. 151.
Conus millipunctatus Lamarck. Theobald, 1860, Catal. Rec. Sh. Mus. Asiat. Soc. Bengal, p. 23.
Conus literatus Linné var. *millepunctatus* Lamarck. Tryon, 1884, Man. Conch., 6: 10, pl. 2, fig. 19.
Conus millepunctatus Hwass. Von Martens and Thiele, 1903, Beschr. Gastrop. Deutsche Tiefsee Exp., p. 136.
Cucullus pardus Bolten. Iredale, 1929, Mem. Queensl. Mus., 9: 282. (error. *pardus* Röding, 1798 = *litteratus* Linné, 1758.)
Conus litteratus Linné var. *millepunctata* Lamarck. Dautzenberg and Bouge, 1933, Jour. Conchyl., 77: 78.

Conus millepunctatus Lamarck var. *aldrovandi* Dautzenberg, 1937, Mém. Mus. Roy. Hist. Nat. Belg., 2(18): 171. (non *aldrovandi* Risso, 1826.)

Conus litteratus pardus (Bolten). Suvatti, 1938, Molluscs of Siam, p. 39.

Conus litteratus pardus (Röding). Kira, 1955, Coloured Illus. Shells Japan, p. 72.

Lithoconus leopardus (Röding). Kaicher 1956, Indo-Pacific Sea Shells, Sect. 5, pl. 5, fig. 13.

DESCRIPTION: Shell massive, conical. Body whorl with very obscure striae; base truncate; aperture rather narrow, the sides parallel. Shoulder smooth; spire depressed, spirally canaliculate and striate. Color of body whorl cream white, with many encircling rows of oblong bluish brown to black spots. One or two rows of small spots often alternate with one or two rows of large ones. The spots are more pronounced in smaller individuals. The body whorl of juvenile specimens is dark cream with narrow transverse white bands on which the dark spots are superimposed. The latter are more square than in adult specimens. Specimens 15 cm. or more in length may be almost completely unmarked. Color of aperture white or pale orange, sometimes yellow at the base. Periostracum olive brown, very thick, opaque. In life, exposed soft parts yellowish white, mottled with brown.

LENGTH: Ordinarily 150–200 mm. This species is the largest representative of the genus in Hawaii. A specimen in the collection of Mr. C. S. Weaver of Honolulu measures 221 × 124 mm.

TYPE LOCALITY: None.

REMARKS: *Conus leopardus* may be distinguished from *C. litteratus* Linné, its closest relative, by the following characteristics: *C. litteratus*, which does not occur in Hawaii, attains a length of only about 5 inches. It generally reaches its maximum width anterior of the shoulder, rather than at the shoulder, as in *C. leopardus*. The base of *C. litteratus* is pointed rather than truncate, and it typically bears a black smudge at the base of the aperture. The spots are more nearly similar in size and more square, and the shell typically bears two broad yellow bands.

C. leopardus is occasionally found on reef platforms but occurs more commonly in depths of one fathom or more in bays and offshore. It is known to occur to a depth of 12 fathoms. Pleistocene fossils of *C. leopardus* are known from Oahu (Ostergaard, 1928).

Conus litoglyphus Hwass *in* Bruguière

Conus capitaneus var. δ. Gmelin, 1791, Syst. Nat., ed. 13, p. 3377.

Conus capitaneus var. ζ. Gmelin, 1791, Syst. Nat., ed. 13, p. 3377.

Conus litoglyphus Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 692, pl. 338, fig. 8.

Cucullus cinamomeus Röding, 1798, Mus. Boltenianum, p. 43.

Cucullus orleanus Röding, 1798, Mus. Boltenianum, p. 44.

Conus subcapitaneus Link, 1807, Beschr. Nat.-Samml. Univ. Rostock, Abt. 3, p. 103.

Conus lithoglyphus Bruguière. Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 280.

Conus lithoglyphus Lamarck. Dufo, 1840, Ann. Sci. Nat., Ser. 2, 14: 175.

Conus lacinulatus Kiener, 1845, Spéc. Gén. Icon. Coq. Viv., 2: pl. 108, fig. 2, p. 312.

Conus carpenteri Crosse, 1865, Jour. Conchyl., 13: 302, pl. 9, fig. 1.

(?) *Conus seychellensis* Nevill, 1874, Jour. Asiatic Soc. Bengal, 43(2): 22.

Conus lithoglyphus Reeve. Tomlin, 1937, Proc. Malac. Soc. Lond., 22: 268.

Dauciconus ermineus (Born). Cotton, 1945, Rec. South Austral. Mus., 8: 246.

Conus lithographus. Platt, 1949, Natl. Geog. Mag., 96: 53, fig. 2.

Conus inermis Born. Tinker, 1952, Pacific Sea Shells, p. 40.

Lithoconus ermineus (Born). Kaicher, 1956, Indo-Pacific Sea Shells, Sect. 5, pl. 4, fig. 10.

DESCRIPTION: Shell elongate; body whorl faintly and distantly striate toward the base,

the striae obsolutely tuberculate. Aperture very narrow, the sides parallel. Color of body whorl dull yellow, reddish brown, or chestnut, often darker at the base, banded at the center and shoulder with rows of white blotches. Spire with alternate brown and white maculations on each whorl. Interior of aperture white.

LENGTH: 50 mm.

TYPE LOCALITY: "Mers des grandes Indes."

REMARKS: This species has often been referred to as *Conus ermineus* Born (Dautzenberg, 1937). Although Born did not provide a figure of *C. ermineus* and his brief description has been held by some (Burch, 1955) to be inadequate, the first figure reference given by Born (Valentyn, 1773: pl. 5, fig. 47) is a fairly good representation of the species under discussion. However, as was first pointed out by Brauer (1878), the two specimens on which Born's original description was based (Naturhistorisches Museum, Vienna, Nos. 4051 and 4052) are not conspecific with *C. litoglyphus* Hwass. Born's specimens are of the species later described by Lamarck (1810: 281) as *C. narcissus*.

Conus litoglyphus occurs rarely on Hawaiian reefs. It has been collected at a depth of 30 fathoms.

Conus lividus Hwass *in* Bruguière

Fig. 17 in Plate 1

Conus rusticus var. β Gmelin, 1791, Syst. Nat., ed. 13, p. 3383. (non *rusticus* Linné, 1758.)

Conus lividus Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 630, pl. 321, fig. 5.

Conus rusticus Linné (Gmelin). Schreibers, 1793, Conchylienkenntniss, 1: 26.

Cucullus monachus Röding, 1798, Mus. Boltenianum, p. 39.

Conus plebejus Link, 1807, Beschr. Nat.-Samml. Univ. Rostock, Abt. 3, p. 106.

Conus lividus Bruguière. Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 36.

(?) *Conus balteatus* Sowerby, 1833, Conch. Illus., p. 3, pt. 37, fig. 58.

Conus lividus Lamarck. Quoy and Gaimard, 1834, Voy. *Astrolabe* Zool., 3: 98, pl. 53, figs. 19–21.

Conus sanguinolentus Quoy and Gaimard, 1834, Voy. *Astrolabe* Zool., 3: 99, pl. 53, fig. 18.

Conus lividus Linné. Krauss, 1848, Die Südafrikanischen Molluscen, p. 130.

Conus rusticus Linné. Mörch, 1857, Catal. Suenson, p. 32. (error).

Conus citrinus Gmelin. Sowerby, 1857, Thes. Conchyl., 3: 4, pl. 4, fig. 70. (error).

(?) *Conus bocki* Sowerby, 1881, Proc. Zool. Soc. Lond., 1881: 636, pl. 56, fig. 7.

(?) *Conus prytanis* Sowerby, 1882, Proc. Zool. Soc. Lond., p. 117, pl. 5, fig. 1.

Conus plebeius Link. Tomlin, 1937, Proc. Malac. Soc. Lond., 22: 293.

Virgiconus lividus (Bruguière). Cotton, 1945, Rec. South Austral. Mus., 8: 254.

Rhizoconus lividus (Bruguière). Kira, 1955, Coloured Illus. Shells Japan, p. 75.

Stephanoconus lividus (Hwass). Kaicher, 1956, Indo-Pacific Sea Shells, Sect. 5, pl. 2, fig. 13.

DESCRIPTION: Shell solid, with widely spaced transverse slightly elevated striae on the body whorl, the striae obsolete near the shoulder but strongly granulated basally. Aperture narrow, the sides parallel. Shoulder coronate; spire obtuse, coronated with large tubercles, striate, often eroded. Color olivaceous or orange brown, with tubercles of the spire and a transverse band below the shoulder white or bluish white. A central band on the body whorl light yellow, white, or bluish white. Color of aperture violet with a pale central transverse band; margin of outer lip yellow. Periostracum greenish brown, thick, opaque. In life, foot, rostrum and siphon black, finely mottled with more or less red, appearing reddish black.

LENGTH: Usually to 60 mm. A specimen 76 mm. in length, collected near Nanakuli, Oahu, is in the collection of Mr. A. M. Harrison of Honolulu.

TYPE LOCALITY: "Antilles," "Isle-de-France

& aux Indes orientales." The first locality is undoubtedly in error. Île de France was an eighteenth-century French name for Mauritius, which was probably the source of Hwass's specimens.

REMARKS: *C. lividus* is one of the two most abundant species of *Conus* on Hawaiian coral reef platforms, the other being *C. flavidus*.

Conus marmoreus Linné

Fig. 9 in Plate 1

Conus marmoreus Linné, 1758, Syst. Nat., ed. 10, p. 712.
Conus nocturnus Solander, 1786, Cat. Portland Mus., p. 156, no. 3411.
Conus marmoratus Linné. Herbst, 1788, Hist. Verm., p. 176, pl. 43, fig. 1. (Not seen.)
Conus bandanus Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 611, pl. 318, fig. 5.
Conus nocturnus Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 611, pl. 318, fig. 1.
[*Conus tigrinus* Humphrey, 1797, Mus. Calonnianum, p. 13.]
[*Conus nigritus* Humphrey, 1797, Mus. Calonnianum, p. 13.]
Cucullus marmoreus (Gmelin). Röding, 1798, Mus. Boltenianum, p. 38.
Cucullus proarchithalassus Röding, 1798, Mus. Boltenianum, p. 38.
Conus proarchithalassius (Bolten). Link, 1807, Beschr. Nat.-Samml. Univ. Rostock, Abt. 3, p. 105.
Conus marmoreus Bruguière. Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 29.
Conus bandanus Bruguière. Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 29.
Conus nocturnus Bruguière. Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 30.
Conus maculatus Perry, 1811, Conchology, pl. 24, fig. 4.
Conus bandanus Lamarck. Sowerby, 1839, Conch. Illus., p. 4, pt. 155–156, fig. 121.
Conus nocturnus Lamarck. Sowerby, 1839, Conch. Illus., p. 4, pt. 155–156, figs. 122, 123.
Coronaxis bandanus (Lamarck). Swainson, 1840, Treatise on Malacol., p. 311.
Conus proarchithalassus (Bolten). Mörch, 1852, Catal. Conchyl. Yoldi, p. 64.
Conus deburghiae Sowerby, 1857, Thes. Conchyl., 3: 2, pl. 1, figs. 6, 7.
Conus nigrescens Sowerby, 1859, Proc. Zool. Soc. Lond., pt. 27: 429, pl. 49, fig. 2.
Conus crosseanus Bernardi, 1861, Jour. Conchyl., 9: 168, pl. 6, figs. 5, 6.
Conus pseudomarmoreus Crosse, 1875, Jour. Conchyl., 23: 223, pl. 9, fig. 4.
Conus marmoreus bandanus Hwass. de Burros e Cunha, 1933, Mem. Estud. Mus. Zool. Univ. Coimbra, Sér. 1, No. 71: 10.
Coronaxis bandanus (Bruguière). Cotton, 1945, Rec. South Austral. Mus., 8: 235.
Cucullus marmoreus (Linné). Kira, 1955, Coloured Illus. Shells Japan, p. 72.
Cucullus bandanus (Bruguière). Kira, 1955, Coloured Illus. Shells Japan, p. 72.
Conus marmoreus bandanus Lamarck. Kaicher, 1956, Indo-Pacific Sea Shells, Sect. 5, pl. 3, fig. 6.

DESCRIPTION: Shell large; body whorl obsoletely striate, its maximum diameter slightly anterior of the shoulder; aperture rather narrow, with almost parallel margins. Shoulder strongly coronate; spire depressed, coronate, striate. Large triangular pale flesh-colored markings separated by dark brown and crowded in two areas form broad irregular bands on the body whorl in specimens from the Hawaiian Islands, the anterior band being narrower. Aperture white or pale pink. Periostracum thin, yellow, translucent. In life, foot tan, siphon banded proximally from the tip with red, white, and black bands.

LENGTH: Usually to 100 mm. A specimen from Oahu in the B. P. Bishop Museum measures 139 mm.

TYPE LOCALITY: Asia.

REMARKS: Hawaiian representatives differ from typical *C. marmoreus*, in which the white markings are larger and less crowded and do not form bands. In some localities, such as New Caledonia (Crosse and Marie, 1874),

Bikini, the Philippines, both forms occur together, with intergrades. To the writer's knowledge, none of the typical forms of *C. marmoreus* have ever been collected in the Hawaiian Islands. The form found in Hawaii (and elsewhere) was described as *C. bandanus* Hwass *in* Bruguière. Most authorities regard the latter as a variety of *C. marmoreus*, which is probably valid in areas where both, as well as intergrades, occur. However, it is probably legitimate to consider the Hawaiian populations as belonging to the subspecies *Conus marmoreus bandanus* Hwass *in* Bruguière. It occurs uncommonly on Hawaiian reefs and has been collected at a depth of eight fathoms.

Conus miles Linné

Fig. 6 in Plate 1

Conus miles Linné, 1758, Syst. Nat., ed. 10, p. 713.
Cucullus miles (Gmelin). Röding, 1798, Mus. Boltenianum, p. 43.
Conus miles Lamarck. Dufo, 1840, Ann. Sci. Nat., Ser. 2, 14: 171.
Leptoconus miles (Linné). Adams and Adams, 1853, Gen. Rec. Moll., 1: 252.
Rhizoconus miles (Linné). Frauenfeld, 1869, Verh. k.k. Zool.-Bot. Ges. Wien, 19: 863.
Lithoconus miles (Linné). Kaicher, 1956, Indo-Pacific Sea Shells, Sect. 5, pl. 5, fig. 3.

DESCRIPTION: Shell solid, with a moderately elevated spire. Body whorl smooth except for raised granular transverse ridges near the base. Aperture narrow, the sides parallel; outer lip thin. Shoulder obsoletely coronate; spire obsoletely tuberculate or plicate, rather faintly striate, concave in young individuals to straight or convex in larger ones. Color of body whorl yellowish white, with a broad, transverse blackish brown band above the center of the body whorl, and another at the base. The bands may be divided transversely into lighter and darker portions. Above and below the upper band, shell marked by narrow threadlike longitudinal dark brown lines, which are continuous on the spire; the lines becoming more closely spaced in older individuals. The broad brown bands, alternating with white, are visible within the aperture. Periostracum greenish brown, with transverse rows of tufted ridges on the body whorl. In life, exposed soft parts greenish black.

LENGTH: 80 mm.

TYPE LOCALITY: India.

REMARKS: *C. miles* is rare on Hawaiian coral reefs and marine benches but occurs more commonly at depths of one to several fathoms. It has been collected at a depth of 26 fathoms.

Conus moreleti Crosse

Fig. 16 in Plate 1

Conus elongatus Reeve, 1843, Conch. Icon., 1: pl. 27, fig. 157. (non *elongatus* Borson, 1820.)
Conus oblitus Reeve, 1849, Conch. Icon., 1(Emendns.): 1. (non *oblitus* Michelotti, 1847.)
Conus moreleti Crosse, 1858, Rev. Mag. Zool., Ser. 2, 10: 122.
Conus lividus Hwass var. *elongatus* Reeve. Weinkauff, 1874, Jahrb. Deutsch. Malak. Ges., 1: 262.
Conus lividus Bruguière var. *moreleti* Crosse. Paetel, 1887, Catal. Conch.-Samml. Paetel, 1: 299.
Stephanoconus moreleti (Crosse). Kaicher, 1956, Indo-Pacific Sea Shells, Sect. 5, pl. 2, fig. 14.

DESCRIPTION: Shell elongate, body whorl with raised, obsoletely knobbed striae basally, otherwise smooth; aperture very narrow, the sides parallel; outer lip thin. Shoulder coronate; spire low, convex, coronate, striate. Color of body whorl yellowish brown or olive, darker at the base, with lighter transverse bands at the shoulder and at the middle. Interior of aperture deep violet, outer lip yellow. Periostracum yellowish brown, rather thin, translucent, forming tufts on the tubercles.

LENGTH: 50 mm.

REMARKS: *C. moreleti* may be distinguished from *C. lividus*, its closest relative, by its elongate shape and small and closely spaced tubercles on the shoulder. It is rare on Hawaiian reefs but occurs more commonly at depths of a few fathoms.

Conus nussatella Linné

Fig. 19 in Plate 1

Conus nussatella Linné, 1758, Syst. Nat., ed. 10, p. 716.
Conus mussatellana Linné. Schröter, 1782, Mus. Gottwald., p. 23, pl. 13, figs. 96[a], 96[b], 96[c]; pl. 43, fig. 52[a].
[*Conus punctulatus major* Humphrey, 1797, Mus. Calonnianum, p. 15.]
Cucullus nussatella (Gmelin). Röding, 1798, Mus. Boltenianum, p. 50.
Hermes nussatellus (Linné). Montfort, 1810, Conchyl. Syst., 2: 399.
Coni nussatellae Linné. Müller, 1836, Synopsis Nov. Gen. Spec. Var. Testaceorum Viventum, p. 122.
Conus nussatella Lamarck. Dufo, 1840, Ann. Sci. Nat., Ser 2, 14: 178.
Hermes nussatula (Linné). Adams and Adams, 1853, Gen. Rec. Moll., 1: 256.
Conus nusatella Linné. Mörch, 1854, Catal. Hencks, p. 21.
Conus nusatella Linné. Weinkauff, 1873, Syst. Conch. Cab., ed. 2, 4: 151.
Hermes nussatella Linné. Schmeltz, 1874, Catal. Mus. Godeffroy, 5: 136.
Hermes nusatellata (Linné). Brazier, 1877, Proc. Linn. Soc. New South Wales, 1: 291.
Conus nussatellata Linné. Brazier, 1879, Jour. Conchol., 2: 192.

DESCRIPTION: Shell cylindrical, rather thin. Body whorl closely striate, the striae minutely granular. Aperture narrow, flaring slightly basally. Shoulder rounded; spire high, convex; apex sharp. Color yellowish white, clouded irregularly with orange brown or light purplish brown longitudinal splotches; with transverse rows of numerous small dark orange brown spots on the body whorl and spire. Periostracum thin, yellow, translucent.

LENGTH: 60 mm.

TYPE LOCALITY: "Nussatello Insulam Asiae."

REMARKS: *C. nussatella* is a rare species in the Hawaiian Islands. Pleistocene fossils have been collected on Oahu by Ostergaard (1928) and the writer.

Conus obscurus Sowerby

Fig. 36 in Plate 2

Conus obscurus Sowerby, 1833, Conch. Illus., p. 2, pt. 29, fig. 26.
Conus obscurus Humphreys MSS. Reeve, 1843, Conch. Icon., 1: pl. 16, fig. 82.
Conus obscurus Reeve. Kiener, 1845, Spéc. Gén. Icon. Coq. Viv., 2: pl. 68, fig. 2, p. 347.
Nubecula obscura (Humphreys). Adams and Adams, 1853, Gen. Rec. Moll., 1: 249.
Conus tulipa Linné, juv. Pease, 1868, Am. Jour. Conch., 4: 126. (error).
Conus obscurus (Hwass) Reeve. Dautzenberg, 1937, Mém. Mus. Roy. Hist. Nat. Belg., 2: 193, pl. 3, fig. 9.
Conus halitropus Bartsch and Rehder, 1943, Proc. Biol. Soc. Wash., 56: 88.
Conus halitropus Dall, Bartsch and Rehder. Greene, 1953, Ann. Rept. Amer. Malacol. Union, Bull. 20: 28.
Tuliparia obscura (Reeve). Kuroda, 1955, Venus: Jap. Jour. Mal., 18: 291.
Gastridium obscurum (Sowerby). Kuroda, 1956, Venus: Jap. Jour. Mal., 19: 80.

DESCRIPTION: Shell elongate-ovate, very thin. Body whorl smooth except for very fine transverse grooves basally. Aperture rather broad, flaring basally. Shoulder smooth; spire moderately elevated, striate; apex pointed. Shell marked by irregularly shaped and distributed blotches and dots of light brown; the lighter areas separating them are violet. Periostracum very thin, translucent.

LENGTH: 30 mm.

TYPE LOCALITY: Arabia.

REMARKS: *C. obscurus* occurs rarely in shal-

low water in Hawaii and is apparently more common at depths of several fathoms.

Conus pennaceus Born

Fig. 3 in Plate 1

Conus pennaceus Born, 1780, Test. Mus. Caes. Vind., p. 167, pl. 7, fig. 14.
Conus aulicus var. α Gmelin, 1791, Syst. Nat., ed. 13, p. 3394.
Conus aulicus var. β Gmelin, 1791, Syst. Nat., ed. 13, p. 3394.
Conus aulicus var. γ Gmelin, 1791, Syst. Nat., ed. 13, p. 3394.
Conus aulicus var. ε Gmelin, 1791, Syst. Nat., ed. 13, p. 3394.
(?) *Conus omaria* Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 743, pl. 344, fig. 3.
Conus rubiginosus Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 746, pl. 344, figs. 1, 2.
(?) *Conus praelatus* Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 746, pl. 345, fig. 4.
(?) *Conus episcopus* Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 748, pl. 345, figs. 2, 6. (In part.)
(?) *Conus crocatus* Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 424.
(?) *Conus colubrinus* Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 433.
Conus pennaceus Bruguière. Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 434.
Conus omaria Hwass var. β. Reeve, 1843, Conch. Icon., 1: pl. 32, sp. 177, figs. 177a, 177b.
Conus pennaceus Lamarck. Reeve, 1843, Conch. Icon., 1: pl. 32, sp. 177.
(?) *Conus elisae* Kiener, 1845, Spéc. Gén. Icon. Coq. Viv., 2: pl. 64, figs. 1, 1a, p. 341.
(?) *Conus stellatus* Kiener, 1845, Spéc. Gén. Icon. Coq. Viv., 2: pl. 99, fig. 3, p. 225.
Conus madagascariensis Sowerby, 1858, Thes. Conchyl., 3: 43, pl. 24, fig. 582.
Conus racemosus Sowerby, 1873, Proc. Zool. Soc. Lond., 1873: 721, pl. 59, fig. 11.
Conus auratus Hwass. Ostergaard, 1928, Bull. Bishop Mus., 51: 4, 29. (error).
Darioconus racemosus (Sowerby). Cotton, 1945, Rec. South Austral. Mus., 8: 257.
Darioconus pennaceus (Born). Cotton, 1945, Rec. South Austral. Mus., 8: 257.
Conus auratus Hwass. Morris, 1952, Field Guide to Shells Pac. Coast & Hawaii, p. 202, col. pl. 7, fig. 3. (error).
Cylinder pennaceus (Born). Kaicher, 1956, Indo-Pacific Sea Shells, Sect. 5, pl. 7, fig. 13.

DESCRIPTION: Shell ventricose, robust, broad at the shoulder; maximum diameter equal to or greater than one half the shell length. Body whorl obsoletely striate, the striae more pronounced basally. Aperture rather broad, flaring slightly basally. Shoulder smooth, usually somewhat rounded, but variable. Spire variable, depressed to moderately elevated, concave to slightly convex, obsoletely striate; protoconch nipplelike, rose colored. Ground color reddish brown (yellow specimens are occasionally found), with narrow transverse closely spaced lines, finely dotted with white. These areas are interrupted by large white subtrigonal blotches, grouped together like scales, usually forming a central band and sometimes additional bands at the shoulder and base. Color pattern of the body whorl usually continued on the spire. Interior of aperture white or bluish white. In life, foot pale brown mottled with darker brown; tip of siphon vermillion, followed proximally by white and black bands.

LENGTH: Usually to 65 mm. A specimen in the U. S. National Museum, collected at Hilo, Hawaii, measures 82 mm. in length.

TYPE LOCALITY: China.

REMARKS: Most specimens found in Hawaii agree fairly well with the original description and figure, although there is considerable morphological variation.

C. pennaceus is extremely similar to *C. omaria* Hwass *in* Bruguière. Tryon (1884) and some other authors have synonymized the two. Kiener (1849–1850: 340) listed characteristics by which the two species may be distinguished, stating under *C. pennaceus*, "C'est avec le *Conus omaria* que cette espèce a le plus d'analogie; le système de coloration de ces deux coquilles est à peu près semblable;

seulement, dans l'espèce ici décrite, les grandes zones sont plutôt longitudinales que transverses, et le réseau qui les constitue n'est pas aussi nettement limité. La form d'ailleurs est également différente; elle est toujours plu raccourcies et plue ventrue." The present writer has found that these distinctions generally hold, but it would be difficult to classify a small percentage of specimens collected in Hawaii using these criteria. If the two species eventually prove to be synonymous, the name *C. pennaceus* has priority over *C. omaria*.

C. pennaceus is one of the most common species on Hawaiian coral reef platforms. Fossils are known from Pleistocene deposits on Molokai (Ostergaard, 1939, as *C. omaria*).

C. elisae Kiener, here listed questionably as a synonym, is possibly a valid species. For an account of it, see page 396.

Conus pertusus Hwass *in* Bruguière

Fig. 31 in Plate 2

Conus nobilis Linné. Schröter, 1783, Einl. Conchyl., 1: 36, pl. 1, fig. 4. (error).
Conus pertusus Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 686, pl. 336, fig. 2.
Conus pertusus Bruguière. Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 278.
Conus amabilis Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 425.
Conus festivus Dillwyn, 1817, Descr. Cat. Rec. Shells, 1: 413.
(?) *Conus inquinatus* Reeve, 1849, Conch. Icon. Suppl., pl. 5, sp. 251.
Hermes pertusus (Hwass). Adams and Adams, 1853, Gen. Rec. Moll., 1: 256.
Conus pertusus Lamarck. Sowerby, 1858, Thes. Conchyl., 3: 23, pl. 13, fig. 273.
Leptoconus pertusus. Schmeltz, 1874, Catal. Mus. Godeffroy, 5: 136.
Pionoconus pertusus (Bruguière). Cotton, 1945, Rec. South Austral. Mus., 8: 249.
Rhizoconus pertusus (Bruguière). Kuroda, 1955, Venus: Jap. Jour. Mal., 18: 290.
Lithoconus pertusus (Hwass). Kaicher, 1956, Indo-Pacific Sea Shells, Sect. 5, pl. 5, fig. 4.

DESCRIPTION: Shell conical; body whorl encircled by distantly spaced punctate striae; aperture rather narrow, sides parallel. Shoulder smooth; spire low, convex, rather obtuse. Color rose, flaked with yellow or white, banded with two interrupted transverse rows of white or light pink blotches below the shoulder and centrally on the body whorl.

LENGTH: 40 mm.

TYPE LOCALITY: "Grandes Indes."

REMARKS: *Conus pertusus* is uncommon in Hawaii. It is known to occur subtidally to a depth of 25 fathoms.

Conus pulicarius Hwass *in* Bruguière

Fig. 12 in Plate 1

Conus pulicarius Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 622, pl. 320, fig. 2.
Conus fustigatus Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 623, pl. 320, fig. 1.
Cucullus punctulatus Röding, 1798, Mus. Boltenianum, p. 40.
Conus pulicarius Bruguière. Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 34.
Conus fustigatus Bruguière. Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 35.
Conus pulicarius Lamarck. Dufo, 1840, Ann. Sci. Nat., Ser. 2, 14: 174.
Conus vautieri Kiener, 1845, Spéc. Gén. Icon. Coq. Viv., 2: pl. 100, fig. 3, p. 350.
Conus fustigatus Lamarck. Reeve, 1849, Conch. Icon. Temp. Index (Critical Analysis), unpaginated.
Puncticulis pulicarius (Hwass). Frauenfeld, 1869, Verh. k.k. Zool.-Bot. Ges. Wien, 19: 863.
Puncticulis pulicarius (Bruguière). Kuroda, 1955, Venus: Jap. Jour. Mal., 18: 289.

DESCRIPTION: Shell thick and solid; body whorl with impressed transverse striae basally; aperture rather narrow, sides parallel. Shoulder coronate; spire moderately elevated, striate, coronate. Color white with dark brown to black spots, the spots often crowded into two transverse bands, one on each side of the center. Spire white, marked sparingly with

brown dots. Periostracum yellow, very thin and translucent in young individuals, thicker and brown in larger specimens. In life, foot and rostrum pale tan mottled with yellowish to reddish brown; tip of siphon reddish orange, followed proximally by pale buff and black bands.

LENGTH: Usually to 60 mm. A specimen collected by W. H. Christensen at Ala Moana Reef, Oahu, measures 74 × 42 mm. A specimen collected by C. S. Weaver measures 73 × 44 mm.

TYPE LOCALITY: Pacific Ocean.

REMARKS: *C. pulicarius* occurs in patches of sand on reef platforms and in bays. It has been collected at depths exceeding 40 fathoms.

Conus quercinus Solander

Fig. 4 in Plate 1; Fig. 23 in Plate 2

Conus quercinus Solander *in* Cat. Portland Mus., 1786, p. 67, no. 1501.
Conus cingulum Gmelin, 1791, Syst. Nat., ed. 13, p. 3378.
Conus quercinus Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 681, pl. 332, figs. 5, 6.
Conus quercinus Bruguière. Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 276.
Conus guercinus Hwass. Blainville, 1818, Dict. Sci. Nat., 10: 249.
Conus quercinus Lamarck. Dufo, 1840, Ann. Sci. Nat., Ser. 2, 14: 172.
Dendroconus quercinus (Hwass). Adams and Adams, 1853, Gen. Rec. Moll., 1: 250.
Conus ponderosus Sowerby, 1858, Thes. Conchyl., 3: 54.
Lithoconus quercinus (Bruguière). Frauenfeld, 1869, Verh. k.k. Zool.-Bot. Ges. Wien, 19: 863.
Cleobula quercina (Solander). Cotton, 1945, Rec. South Austral. Mus., 8: 260.
Lithoconus quercinus (Hwass). Kaicher, 1956, Indo-Pacific Sea Shells, Sect. 5, pl. 5, fig. 9.

DESCRIPTION: Shell large and solid, variable in obesity. Body whorl obsoletely striate, the striae becoming more pronounced basally; aperture rather wide, sides parallel. Shoulder smooth, rounded. Spire depressed, concave, striate; apex raised. Color of body whorl yellow, encircled with numerous closely spaced transverse threadlike brown lines; spire usually paler yellow; interior of aperture white. Periostracum thick, brown, opaque. In life, foot and siphon brownish gray, heavily speckled with black.

LENGTH: Usually to 100 mm. A specimen from Oahu in the B. P. Bishop Museum measures 134 mm.

TYPE LOCALITY: None.

REMARKS: *C. quercinus* is found in large sandy areas in bays and to depths of more than 40 fathoms.

Conus rattus Hwass *in* Bruguière

Fig. 30 in Plate 2

Conus rattus Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 700, pl. 338, fig. 7.
Conus taitensis Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 713, pl. 336, fig. 9.
Conus capitaneus var. C. Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 266.
Conus rattus Bruguière. Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 408.
Conus taitensis Bruguière. Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 424.
Conus capitaneus var. B. Küster, 1837–1840, Syst. Conch. Cab., ed. 2, 4: 8, pl. 14, figs. 13, 14.
Conus taheitensis Hwass. Reeve, 1843, Conch. Icon., 1: pl. 15, sp. 78.
Conus rattus Lamarck. Reeve, 1843, Conch. Icon., 1: sp. 78.
Conus taheitensis Hwass var. *rattus* Lamarck. Catlow and Reeve, 1845, Conchol. Nomencl., p. 322.
Leptoconus rattus (Lamarck). Adams and Adams, 1853, Gen. Rec. Moll., 1: 252.
Leptoconus taheitensis (Hwass). Adams and Adams, 1853, Gen. Rec. Moll., 1: 252.
Conus taheitensis Bruguière. Sowerby, 1857, Thes. Conchyl., 3: 5, pl. 2, fig. 26.

Conus viridis Sowerby, 1857, Thes. Conchyl., 3: 20, pl. 5, fig. 102.
Conus tahitiensis Bruguière. Schmeltz, 1865, Catal. II Godeffroy, p. 20.
Conus rattus Solander. Schaufuss, 1869, Molluscorum Syst. Cat. Paetel, p. 45.
Conus tahitensis Bruguière. Schaufuss, 1869, Molluscorum Syst. Cat. Paetel, p. 45.
Conus ratus var. *tahitensis*. Ostergaard, 1928, B. P. Bishop Mus. Bull. 51: 29.
Conus tahitiensis Hwass (emend.). Dautzenberg and Bouge, 1933, Jour. Conchyl., 77: 89.
Rhizoconus rattus (Bruguière). Cotton, 1945, Rec. South Austral. Mus., vol. 8, p. 252.
Conus tahitensis Hwass. Mermod, 1947, Rev. Suisse Zool., 54: 208.
Lithoconus rattus (Hwass). Kaicher, 1956, Indo-Pacific Sea Shells, Sect. 5, pl. 5, fig. 1.

DESCRIPTION: Shell of moderate thickness; body whorl obsoletely striate near the shoulder, but distinctly so near the base, the striae closely spaced; aperture rather narrow, sides nearly parallel. Shoulder angular, smooth; spire rather low, obtuse, striate. Color of body whorl yellowish or violet brown, with large bluish white spots and maculations forming an interrupted central band and another at the shoulder. Shell below central band densely flecked with white, above band sparsely flecked with white. Spire with alternate brown and white blotches, continuing to form band on body whorl at shoulder. Aperture violet within. Periostracum thin, yellow, translucent, smooth or with raised ridges near growing edge. In life, foot, rostrum and siphon dark olive green, mottled with black.

LENGTH: Usually to 40 mm. A specimen collected by T. H. Richert on windward Oahu, and presently in the collection of the Children's Museum of Honolulu, measures 60 mm.

TYPE LOCALITY: "Mers d'Amerique," undoubtedly in error.

REMARKS: *C. rattus* occurs not uncommonly both on intertidal benches and on subtidal reef platforms. Pleistocene fossils are known from Oahu (Ostergaard, 1928) and Maui (Ostergaard, 1939).

Conus retifer Menke

Fig. 32 in Plate 2

Conus retifer Menke, 1829, Verz. Ans. Conch.-Samml. Malsburg, p. 68.
Conus solidus Sowerby, 1834, Conch. Illus., p. 3, pt. 56, fig. 76. (non *solidus* Gmelin, 1791.)
Cylinder solidus (Sowerby). Adams and Adams, 1853, Gen. Rec. Moll., 1: 255.
Darioconus retifer (Menke). Cotton, 1945, Rec. South Austral. Mus., 8: 258.
Cylinder retifer (Menke). Kaicher, 1956, Indo-Pacific Sea Shells, Sect. 5, pl. 7, fig. 10.

DESCRIPTION: Shell very thick and solid, pear-shaped. Body whorl striate; aperture with almost parallel sides. Shoulder rounded, smooth. Spire elevated, acuminated, striate. Color reticulated orange brown with large and small white triangular markings, arranged as scales, and longitudinal chocolate and orange markings mostly interrupted to form two transverse bands. Color pattern of body whorl continued on spire; apex pink. Interior of aperture white or pale pink. Periostracum very thin, pale yellow, very translucent. In life, foot mottled brown. Tip of siphon vermillion, followed proximally by white and black bands.

LENGTH: 50 mm.

TYPE LOCALITY: None.

REMARKS: *C. retifer* is uncommon in Hawaii.

Conus spiceri Bartsch and Rehder

Fig. 8 in Plate 1

Conus spiceri Bartsch and Rehder, 1943, Proc. Biol. Soc. Wash., 56: 87.
Conus spiceri Dall, Bartsch and Rehder. Greene, 1953, Ann. Rept. Amer. Malacol. Union, Bull. 20: 28.

DESCRIPTION: Shell large and thick; body whorl marked by fine incremental lines and closely spaced spiral threads, becoming heav-

ier and more distantly spaced basally. Aperture fairly broad, widening somewhat basally. Shoulder broad, smooth, angular. Spire low, concave, singly striate. Color pale yellow, somewhat darker basally, with obscure white transverse bands. Interior of aperture bluish white. Periostracum thick, yellowish brown.

LENGTH: 110 mm.

TYPE LOCALITY: Midway Island.

REMARKS: This species, which is rather rare, is distinguished from *C. quercinus* in that it lacks the brown spiral lines, has a flatter spire, and is only singly striate on the summit. It is distinguished from *C. distans* by lacking the brown bands and tuberculate shoulder. Its closest relative is *C. virgo* Linné, which does not occur in Hawaii. *C. virgo* is easily distinguished from *C. spiceri* by the pronounced violet color of the base in the former.

To the author's knowledge, no specimens of *C. spiceri* have been collected outside the Hawaiian Islands.

Conus sponsalis Hwass *in* Bruguière

Figs. 38 and 39 in Plate 2

Conus sponsalis Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 635, pl. 322, fig. 1.

(?) *Conus ceylanensis* Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 636, pl. 322, fig. 10.

Conus sponsalis Bruguière. Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 38.

Conus nanus Sowerby, 1833, Conch. Illus., p. 1, pt. 24, fig. 6.

Conus nanus Broderip, 1833, Proc. Zool. Soc. Lond., 1833: 53.

Coronaxis nanus (Broderip). Adams and Adams, 1853, Gen. Rec. Moll., 1: 248.

Coronaxis sponsalis. Adams and Adams, 1853, Gen. Rec. Moll., 1: 248.

Conus sponsalis Solander. Von Martens and Langkavel, 1871, Donum Bismarckianum. Samml. Südsee-Conchyl., p. 31.

Conus ceylonensis Hwass var. *sponsalis*. Tryon, 1884, Man. Conch., 6: 23, pl. 6, fig. 99.

Conus ceylonensis Hwass var. *nanus* Broderip. Tryon, 1884, Man. Conch., 6: 24, pl. 6, fig. 100.

Conus nana Broderip. Paetel, 1887, Catal. Conch.-Samml. Paetel, 1: 302.

Conus ceylanensis Hwass var. *pusillus*. Mant, 1922, Nautilus, 35: 84.

Conus ceylonensis Hwass. Ostergaard, 1935, B. P. Bishop Mus. Bull., 131: 21.

Virroconus sponsalis (Bruguière). Cotton, 1945, Rec. South Austral. Mus., 8: 237.

Stephanoconus sponsalis (Hwass). Kaicher, 1956, Indo-Pacific Sea Shells, Sect. 5, pl. 2, fig. 5.

DESCRIPTION: Shell small but thick and solid, extremely variable with respect to several characteristics. Body whorl usually obsoletely striate, the striae somewhat more pronounced basally; aperture narrow, the sides parallel. Shoulder coronated with small tubercles which may be obsolete in large specimens. Spire usually moderately elevated, inner whorls coronated, but often eroded; 0–3 striae per whorl. Ground color of basal two thirds of body whorl typically pale blue; remaining area near the shoulder white; base tipped with brownish purple. In many specimens, no other coloration is present. Some individuals, chiefly younger specimens, marked with reddish or orange brown on body whorl; these markings generally of two arrangements, one or both of which may be present on the same shell: (1) encircling narrow bands of rather distantly separated dots or dashes separated by white dashes (Fig. 39); (2) interrupted longitudinal blotches of color (Fig. 38). Tubercles white, areas between them sometimes orange brown. Interior of aperture dark violet to brown, with white bands near the shoulder and centrally; outer lip white. Periostracum thin, translucent, sometimes becoming thicker and opaque at the growing edge, or in larger specimens. In life, foot pale pink, mottled with white, darker pink at extremities. Siphon and rostrum pale pink or white, tipped with darker pink; tentacles white.

LENGTH: To 30 mm. Most specimens smaller.

TYPE LOCALITY: "Île Saint-George."

REMARKS: Specimens from Hawaiian populations agree with the original figure and Broderip's (1833) description of *Conus nanus*, which has not generally been considered a distinct species. A number of workers (Pease, 1868; Tryon, 1884; Ostergaard, 1935; Tomlin, 1937; Tinker, 1952) have considered *C. nanus* to be not specifically distinct from *C. ceylanensis*.

C. ceylanensis does not seem to be a well-known species. Specimens from many Indo-West Pacific localities in the U. S. National Museum and Museum of Comparative Zoology collections are indistinguishable from representatives of the Hawaiian populations under consideration.

Examination of specimens from many Indo-West Pacific island groups in the U. S. National Museum, Museum of Comparative Zoology, and Academy of Natural Sciences of Philadelphia, and personal observations of the writer in the Marshall Islands led to the conclusions that the widespread *C. sponsalis* is also extremely variable and that there is sufficient morphological overlap with the Hawaiian forms for the latter to be considered conspecific with *C. sponsalis*. However, since most Hawaiian specimens are morphologically distinguishable from most specimens from other parts of the central and western Pacific, the Hawaiian populations may validly be accorded subspecific rank and termed *C. sponsalis nanus* Sowerby.

Tryon (1884: 24), who was also uncertain of the distinction between *C. sponsalis* and *C. ceylanensis*, considered *C. nanus* a variety of the latter in his arrangement but considered the possibility that both were varieties of *C. sponsalis*. Ostergaard (1935) also listed "*Conus ceylonensis sponsalis*," under which he stated, "I believe that this shell intergrades with *C. ceylonensis* Hwass and should therefore be termed a variety of that species, as Tryon places it."

Although the identity of *C. ceylanensis* remains problematical, the present writer is inclined to agree that it is probably conspecific with *C. sponsalis*. In this case, the name *sponsalis* has page priority, and there seems no reason why it should not take precedence over *ceylanensis*. It is hoped that collections in Ceylon and other Indian Ocean areas, to be made by the writer in the near future, will contribute towards a more definitive solution to this question.

C. sponsalis is one of the most abundant species of *Conus* on intertidal benches in Hawaii. Pleistocene fossils are known from Oahu (Ostergaard, 1928) and Molokai (Ostergaard, 1939).

Conus striatus Linné

Fig. 5 in Plate 1

Conus striatus Linné, 1758, Syst. Nat., ed. 10, p. 716.

Cucullus striatus (Gmelin). Röding, 1798, Mus. Boltenianum, p. 50.

Conus striatus Lamarck. Quoy and Gaimard, 1834, Voy. Astrolabe Zool., 3: 89, pl. 52, figs. 10, 10[1].

Leptoconus striatus (Linné). Adams and Adams, 1853, Gen. Rec. Moll., 1: 254.

Tuliparia striata. Gray, 1857, Guide Moll. Brit. Mus., 1: 5.

Conus floridus Sowerby, 1858, Thes. Conchyl., 3: 47, frontispiece, fig. 558.

Chelyconus striatus (Linné). Frauenfeld, 1869, Verh. k.k. Zool.-Bot. Ges. Wien, 19: 863.

Conus tulipa Linné var. *floridus* Sowerby. Weinkauff, 1874, Jahrb. Deutsch. Malak. Ges., 1: 284.

Phasmoconus striatus (Linné). Cotton, 1945, Rec. South Austral. Mus., 8: 260.

Dendroconus striatus (Linné). Kuroda, 1955, Venus: Jap. Jour. Mal., 18: 292.

DESCRIPTION: Shell large, rather thin, elongate-ovate, the maximum diameter not at the shoulder but about one fifth of the distance from shoulder to base. Body whorl with fine, closely spaced transverse striae; aperture broad, flaring gradually toward the base. Shoulder angular, smooth. Spire striate,

canaliculate, usually concave, often extremely so and depressed below the shoulder, a peculiarity not typically found in specimens from other areas. Ground color pinkish white, irregularly clouded with blotches of brown or purplish brown composed of closely spaced transverse lines. Spire tesselated with brown and white. Interior of aperture white. Periostracum thin, yellow, translucent. In life, foot, siphon and rostrum tan mottled with brown.

LENGTH: Usually to 110 mm. A specimen measuring 120 × 53 mm. is in the collection of C. S. Weaver.

TYPE LOCALITY: "Hitoe."

REMARKS: Specimens from the Hawaiian Islands are characterized by having the spire depressed often to such an extent that the apex does not extend beyond the shoulder of the body whorl. In juvenile specimens, the spire is elevated and the sides of the aperture almost parallel.

C. striatus occurs uncommonly on Hawaiian reefs. It is typically found associated with a sand substratum. Pleistocene fossils of *C. striatus* have been collected by the author on Oahu.

Conus suturatus Reeve

Figs. 24–28 in Plate 2

Conus suturatus Reeve, 1844, Conch, Icon., 1: pl. 45, sp. 250; suppl. pl. 3, fig. 250b.

Dendroconus suturatus (Reeve). Adams and Adams, 1853, Gen. Rec. Moll., 1: 250.

Conus turbinatus Sowerby, 1858, Thes. Conchyl., 3: 25, pl. 10, fig. 227.

Lithoconus hawaiensis Bartsch and Rehder. Kaicher, 1956, Indo-Pacific Sea Shells, Sect. 5, pl. 5, fig. 6.

DESCRIPTION: Shell solid; body whorl obsoletely striate toward the shoulder, the striae more pronounced, impressed but with an adjacent ridge, widely spaced toward the base. In young specimens, the striae are more pronounced over the entire body whorl. Aperture narrow, sides parallel. Shoulder angular, smooth; spire elevated in younger specimens, less so in larger ones, deeply striate, characterized by a ridge on each whorl at the junction of the preceding whorl. Ground color white, with broad transverse bands of orange brown (in smaller specimens) or orange pink (in larger specimens) on the body whorl. Base stained with pale orange brown or pale rose. Interior of aperture white. In smaller specimens, narrow bands of orange brown rectangles encircle the body whorl. Spire maculated with orange brown and white. Periostracum smooth, dark brown, opaque.

Most specimens from Hawaii are characterized by having the spire more elevated than those of the shells described and figured by Reeve.

LENGTH: To 50 mm.

TYPE LOCALITY: Port Essington, Australia.

REMARKS: *C. suturatus* is very closely related to *C. tessulatus*. In the latter, the rows of square or quadrangular blotches persist in adult specimens and vary from orange brown to, more usually, pink. In *C. suturatus*, this pattern is present in young specimens but is gradually superseded by the broad solid orange pink transverse bands mentioned in the description, and the transverse rows of rectangles are usually lost, as the shell grows larger. Some specimens of the two species may be virtually indistinguishable. In young *C. suturatus*, the broad transverse bands typically underly the juvenile pattern, the entire body whorl is usually striate, and the basal striae are accompanied by an adjacent ridge. In young *C. tessulatus* all areas between the rectangular blotches are typically white, impressed spiral striae occur only basally, and the areas between the striae are typically flat. The upper portion of the shell is smooth. Older, larger specimens of these two species are usually distinguishable by differences in color pattern cited in the accompanying descriptions.

C. suturatus is not common in shallow water in Hawaii, but many specimens have been

dredged in 4–50 fathoms off the major islands.

C. ambiguus Reeve (1844, Conch. Icon., 1: pl. 44, sp. 244) appears to be extremely similar and possibly identical. Some specimens collected in Hawaii have been labeled *C. ambiguus*. A definitive statement concerning *C. ambiguus* will not be made here, pending study of type material.

Conus tessulatus Born

Fig. 22 in Plate 2

Conus tessulatus Born, 1778, Ind. Rer. Nat. Mus. Caes. Vind., p. 131.
Conus virgo var. γ Gmelin, 1791, Syst. Nat., ed. 13, p. 3376.
Conus tessellatus Born. Bruguière, 1792, Enc. Meth. Vers, 1: 641.
Cucullus pavimentum Röding, 1798, Mus. Boltenianum, p. 41.
Conus tessellatus Lamarck. Menke, 1828, Synopsis Methodica Molluscorum, p. 45.
Conus tesselatus Lamarck. Dufo, 1840, Ann. Sci. Nat., Ser. 2, 14: 173.
Conus desselatus Lamarck. Reichenbach, 1842, Land.-, Süssw.- u. See-Conch., p. 51, pl. 17, figs. 376, 377.
Conus tessellatus Bruguière. Kiener, 1845, Spéc. Gén. Icon. Coq. Viv., 2: pl. 17, fig. 1, p. 68.
Dendroconus tessellatus (Born). Adams and Adams, 1853, Gen. Rec. Moll., 1: 250.
Conus tessalatus Born. Theobald, 1860, Catal. Rec. Sh. Mus. Asiat. Soc. Bengal, p. 24.
Conus tesselatus Born. Weinkauff, 1874, Jahrb. Deutsch. Malak. Ges., 1: 245.
Conus tesselatus Bruguière. G. R. Batalha, 1878, Catal. Coll. F. R. Batalha, p. 25.
Conus tessellatus Hwass. Dautzenberg, 1893, Bull. Soc. Zool. France, 18: 80.
Conus edaphus Dall, 1910, Proc. U. S. Natl. Mus., 38: 223.
Conus tessullatus Born. Hirase, 1954, Illus. Handbk. Shells, p. 88, pl. 113, fig. 17.
Lithoconus tessulatus (Born). Kaicher, 1956, Indo-Pacific Sea Shells, Sect. 5, pl. 5, fig. 11.

DESCRIPTION: Shell fairly thick and stout. Body whorl smooth near the shoulder, bearing rather widely spaced impressed striae basally; base grooved; aperture narrow, the sides parallel; outer lip thin. Shoulder smooth, angular; spire concave, deeply striate, characterized by a ridge on each whorl at the junction of the preceding whorl; apex pointed. Ground color white, body whorl encircled by rows of quadrangular pinkish orange spots, usually crowded to form two transverse bands. Base characteristically stained with violet. Spire tesselated with pink and white. Interior of aperture white, violet at the base. In life, "yellowish white, foot mottled with brownish buff, anteriorly spotted with black; creeping disk buff yellow with darker veins; siphon creamy yellow tinged with brown, edged with yellow, with a transverse black spot at the anterior end" (Garrett, 1878).

LENGTH: 35–40 mm.

TYPE LOCALITY: Africa.

REMARKS: This species is extremely rare in shallow water in the Hawaiian Islands although it is widely distributed throughout the Indo-West Pacific region and reaches the west coast of Mexico (Hanna and Strong, 1949). Only one specimen collected alive in the Hawaiian Islands is known with certainty to the writer. It was collected by S. Sato in Haleiwa Bay, Oahu, depth 25 feet, and is in the Children's Museum of Honolulu, on loan from Mrs. Jean Bromley.

C. tessulatus was recorded from Hawaii by Garrett (1878). Dautzenberg (1937: 244) states that it was also recorded from Hawaii by P. Fischer, but no further reference is given. Three specimens in the U. S. National Museum, collected by the U. S. Exploring Expedition, are labeled "Sandwich Is." (and are shown in Plate 2, Fig. 22), but this locality datum is not to be considered reliable (J. P. E. Morrison, verbal communication).

Conus textile Linné

Fig. 2 in Plate 1

Conus textile Linné, 1758, Syst. Nat., ed. 10, p. 717.

Conus undulatus Solander *in* Cat. Portland Mus., 1786, p. 180, no. 3866.

Conus archiepiscopus Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 747, pl. 345, fig. 5; pl. 346, figs. 1, 7.

Cucullus auriger Röding, 1798, Mus. Boltenianum, p. 49.

Cucullus gloria-maris Röding, 1798, Mus. Boltenianum, p. 49. (non *Conus gloria-maris* Chemnitz, 1777.)

Cucullus textile (Gmelin). Röding, 1798, Mus. Boltenianum, p. 50.

Conus panniculus Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 435.

Cylinder textile (Linné). Montfort, 1810, Conchyliogie Systematique, 2: 391.

(?) *Conus pyramidalis* Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 438.

Conus gloria-maris Perry, 1811, Conchology, pl. 25, no. 5. (non *gloria-maris* Chemnitz, 1777.)

Conus rete-aureum Perry, 1811, Conchology, pl. 25, no. 5.

Conus textiles Lamarck. Dufo, 1840, Ann. Sci. Nat., Ser. 2, 14: 177.

Conus textilis. Gray, 1842, Fig. Moll. Anim., pl. 10, fig. 1.

Conus victoriae Reeve, 1843, Conch. Icon., 1: pl. 37, figs. 202a, 202b.

Conus verriculum Reeve, 1843, Conch. Icon., 1: pl. 38, figs. 208a, 208b.

Conus concatenatus Kiener, 1845, Spéc. Gén. Icon. Coq. Viv., 2: pl. 110, fig. 1, p. 362.

Conus telatus Reeve, 1848, Conch. Icon., 1: suppl. pl. 1, fig. 270.

Conus scriptus Sowerby, 1858, Thes. Conchyl., 3: 41, pl. 23, fig. 563.

Conus tigrinus Sowerby, 1858, Thes. Conchyl., 3: 41, pl. 23, fig. 569.

(?) *Conus condensus* Sowerby, 1866, Thes. Conchyl., 3: 326, pl. 26, fig. 622.

Conus paniculus Lamarck. Paetel, 1873, Catal. Conch.-Samml. Paetel, p. 51.

Cylindrus textile (Linné). Morelet, 1889, Jour. Conchyl., 37: 133.

Darioconus textile (Linné). Cotton, 1945, Rec. South Austral. Mus., 8: 257.

Darioconus textilis (Linné). Kuroda, 1955, Venus: Jap. Jour. Mal., 18: 291.

DESCRIPTION: Shell large, ventricose, rather thin, subcylindrical-ovate. Maximum diameter of about one half shell length is reached about one fifth of the distance from shoulder to base. Body whorl transversely striate, the striae fine and closely spaced; aperture broad, flaring basally. Shoulder smooth; spire elevated, concave, acuminate, striate. Ground color white, with undulating longitudinal brown lines, interrupted by white triangles arranged as scales, and broad orange brown maculations disposed to form two or three interrupted transverse bands on the body whorl; the maculations streaked longitudinally with waved darker brown lines. Spire similarly marked. Interior of aperture white. Periostracum thin, yellow, translucent. In life, foot mottled brown on white. Tip of siphon reddish orange, followed proximally by bands of white and black; remainder of siphon white with closely spaced narrow brown bands.

LENGTH: To 100 mm.

TYPE LOCALITY: Banda Islands.

REMARKS: *C. textile* is rare in Hawaiian waters. It is found occasionally on reef platforms and to depths of at least 12 fathoms.

Conus vexillum Gmelin

Fig. 11 in Plate 1

Conus vexillum Gmelin, 1791, Syst. Nat., ed. 13, p. 3397.

(?) *Conus sumatrensis* Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 655, pl. 327, fig. 8.

Cucullus canonicus Röding, 1798, Mus. Boltenianum, p. 43. (non *Conus canonicus* Hwass *in* Bruguière, 1792.)

Conus vexillum Linné. De Fremery, 1802, Mus. Meyer., p. 82. (Not seen.)

Conus vexillum Bruguière. Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 268.

(?) *Conus leopardus* Dillwyn, 1817, Descr. Cat. Rec. Shells, 1: 364. (non *leopardus* Röding, 1798.)

Conus sulphuratus Kiener, 1845, Spéc. Gén. Icon. Coq. Viv., 2: pl. 66, fig. 3; pl. 78, fig. 4; p. 130.

Leptoconus vexillum. Adams and Adams, 1853, Gen. Rec. Moll., 1: 252.

Conus planorbis Born. Oostingà, 1928, Misc. Zool. Sumatrana, no. 28: 4. (error. Fide Misc. Zool. Sum., no. 49: 6.)

Rhizoconus vexillum (Gmelin). Cotton, 1945, Rec. South Austral. Mus., 8: 251.

DESCRIPTION: Shell large, rather thin. Body whorl obsoletely striate; aperture rather broad, sides parallel. Shoulder broad, angular, smooth. Spire moderately elevated, obtuse, somewhat canaliculate, striate. Color of body whorl white, broadly banded with yellowish brown, stained with darker brown at the base, with irregular chocolate longitudinal waved lines which often branch and are partially interrupted to form a white band at the middle and another at the shoulder. Spire white with yellow apex and broad radiating chocolate bands, some of which are continuous on the body whorl. Interior of aperture white. Periostracum dark green, thick, opaque, ridged. In life, foot and siphon greenish black.

LENGTH: To 135 mm.

TYPE LOCALITY: None.

REMARKS: Although this species was first reported from Hawaii as *C. vexillum* (Garrett, 1878), it has generally been known in Hawaii as *C. sumatrensis*. Examination of specimens in the U. S. National Museum and in collections made by the author in Micronesia as well as Hawaii revealed morphological overlap and intergrades between typical specimens of both species. Further confusion is found in the literature. Kiener (1847: 81) stated under *C. sumatrensis*, "Coquille qui par sa forme se rapproche de la précédente [*C. vexillum*]; elle est reconnaisable surtout par ses lignes longitudinales ramifées." Tryon (1884: 39) stated, on the other hand, under *C. vexillum*, "Spire often variegated with white and chestnut broad flames, the latter often overlaying also the lighter chestnut of the body whorl." Most authorities have considered the two as distinct species. The figures given in Reeve (1843: pls. 1 and 3) show extreme variants, while the specimens figured by Sowerby (1857: pl. 7) are hardly distinguishable.

C. vexillum is a relatively uncommon species on Hawaiian reefs. It is known to occur to a depth of 25 fathoms. Pleistocene fossils are known from Molokai (Ostergaard, 1939, as *C. sumatrensis*).

Conus vitulinus Hwass *in* Bruguière

Fig. 14 in Plate 1

Conus vitulinus Hwass *in* Bruguière, 1792, Enc. Meth. Vers, 1: 648, pl. 326, fig. 3.

Conus vitulinus Bruguière. Lamarck, 1810, Ann. Mus. Hist. Nat. Paris, 15: 265.

Conus vulpinus Schubert and Wagner, 1829, Syst. Conch. Cab., 12: 56, pl. 222, fig. 3073. (non *vulpinus* Hwass *in* Bruguière, 1792.)

Conus vulpinus Wagner var. A. Küster, 1837–1840, Syst. Conch. Cab., ed. 2, 4: 29, pl. 3, fig. 7. (non *vulpinus* Hwass *in* Bruguière, 1792.)

Conus planorbis var. *vitulinus* Hwass. Mörch, 1852, Catal. Conchyl. Yoldi, p. 69.

Dauciconus vitulinus (Bruguière). Cotton, 1945, Rec. South Austral. Mus., 8: 246.

Leptoconus vitulinus (Bruguière). Kira, 1955, Coloured Illus. Shells Japan, p. 36.

Lithoconus vitulinus (Hwass). Kaicher, 1956, Indo-Pacific Sea Shells, Sect. 5, pl. 2, no. 7a.

DESCRIPTION: Shell thick and solid. Body whorl obscurely striate near the shoulder, the striae becoming more pronounced and granular basally. Aperture narrow, the sides parallel. Shoulder angular, smooth; spire depressed, slightly canaliculate, striate. Color of body whorl usually deep reddish or purplish brown, darker at the base, with white bands mottled with ground color at the shoulder and below the center; the bands contain one to several rows of brown dots. In large specimens, the reddish brown areas often interrupted by longitudinal white blotches. Spire arcuately tesselated with brown and white. Perios-

tracum gray, thick, opaque, closely striate transversely. In life, visible portions of foot and siphon bright lemon yellow.

LENGTH: 70 mm.

TYPE LOCALITY: Indian Ocean.

REMARKS: Small specimens of this species closely resemble *C. litoglyphus*. *C. vitulinus* may be distinguished by having striae above the central band, rows of brown dots on the white bands, and absence of a pointed apex.

C. vitulinus is a relatively uncommon species on Hawaiian reefs. It is known to occur to a depth of 30 fathoms. Pleistocene fossils are known from Molokai (Ostergaard, 1939).

A single specimen labeled *Conus planorbis* Born in the collection of the B. P. Bishop Museum (No. 68990) was dredged in Honolulu Harbor. The Museum of Comparative Zoology contains another specimen (No. 146332) collected at Midway Island by J. Chalean, apparently alive when collected. These specimens are extremely similar to, and may be synonymous with, *C. vitulinus*, as has been suggested by some workers (p. 395).

POSSIBLE ADDITIONAL VALID SPECIES IN HAWAII

Conus elisae Kiener

Fig. 4

Conus elisae Kiener, 1845, Spéc. Gén. Icon. Coq. Viv., 2: pl. 64, figs. 1, 1a, p. 341.

(?) *Conus stellatus* Kiener, 1845, Spéc. Gén. Icon. Coq. Viv., 2: pl. 99, fig. 3, p. 225.

DESCRIPTION: Shell subcylindrical; maximum diameter slightly more than one half the length. Body whorl obsoletely striate, the striae slightly more pronounced and as raised ridges toward the base. Aperture rather broad, flaring slightly basally. Shoulder smooth, rounded. Spire moderately elevated, obtuse, straight or slightly convex, obsoletely striate. Color dark reddish brown, as many closely spaced and intersecting longitudinal lines separated by small white spots; occasionally with larger white subtrigonal blotches as in *C. pennaceus;* two broad transverse bands either side of the center appear to be superimposed on this pattern. These bands are more solidly colored and are similar to the reddish brown areas of *C. pennaceus* in that they bear narrow transverse closely spaced lines finely dotted with white. Color pattern of the spire similar to that of the bands on the body whorl. Interior of aperture bluish white.

FIG. 4. "*Conus elisae* Kiener," 35 × 19 mm. Specimen collected by C. E. Cutress on Rabbit Island, off Oahu. Photograph by C. E. Cutress.

LENGTH: Specimens in the U. S. National Museum and Academy of Natural Sciences of Philadelphia range from 15.5 mm. to 27 mm. in shell length. The specimen illustrated in Figure 3 measures 35 × 19 mm.

TYPE LOCALITY: None.

REMARKS: *Conus elisae* was first reported from Hawaii by Weinkauff (1874). Recently, a number of specimens agreeing with the description and figure of this species have been collected on the islands of Kauai and Niihau. Sowerby (1858: 43) considered this species to be synonymous with *C. pennaceus*, a conclusion with which the present writer has been inclined to agree. However, no specimens intermediate in character between

Kiener's *C. elisae* and typical *C. pennaceus* have been found, despite an increasing number of specimens collected during the past year. Moreover, the microhabitat of the Hawaiian specimens referred to seems to differ from that of typical *C. pennaceus*. The former are typically found buried as deep as six inches under sand (A. H. Cornelison, verbal communication) while the latter are typically found on or partly buried in sand under rocks (Kohn, 1959). It seems reasonable at the present time to consider *C. elisae* as a possibly valid species. The problem requires further investigation.

UNIQUE RECORD FROM HAWAII

Conus smirna Bartsch and Rehder

Fig. 13 in Plate 1

This species is known only from a single specimen, the type, described by Bartsch and Rehder (1943). It was dredged near Lanai ("Ranai") in 257–312 fathoms by the U. S. Fisheries steamer "Albatross."

SPECIES KNOWN IN HAWAII ONLY FROM COLLECTION OF DEAD SPECIMENS

To the author's knowledge, there are no records of living specimens of the following species from the Hawaiian archipelago.

Conus aulicus Linné

C. auratus is probably a synonym of *C. aulicus*.

Ostergaard (1928) listed *C. auratus* as occurring in the fossil state on Oahu. The present writer is quite convinced that the species referred to was *C. pennaceus*, since Ostergaard (1928) also mentions the normal habitat of living specimens. However, at least one fossil specimen of *C. aulicus* is known from Oahu. It was collected about five feet above high tide mark near Nanakuli by E. C. Jones in March, 1954. It is at present in the collection of the Children's Museum of Honolulu (No. 2747).

Specimens now considered to be narrow-shelled variants of *C. pennaceus* because of the abundance of intergrades were listed as *C. auratus* by Edmondson (1933). Edmondson (1946) cited both *C. auratus* and *C. omaria*. The same figure of a rather typical shell of *C. pennaceus* was labelled *C. auratus* by Edmondson (1933) and "*Conus omaria* (?)" in the 1946 edition.

Specimens of *C. aulicus* were collected by the Tanager Expedition at Kure (Ocean) Island and Pearl and Hermes Reef and are in the collection of the B. P. Bishop Museum (Nos. 66438, 66439, 66205). A shell from Midway Island which is quite fresh in appearance but was empty when collected is in the collection of C. A. Allen.

Conus aureus Hwass *in* Bruguière

A number of well-preserved shells of this species have been collected on beaches along the windward coast of Oahu.

Conus auricomus Hwass *in* Bruguière

This species has been known erroneously as *C. clavus* Linné (see Dodge, 1953). Several specimens have been collected from dredged material at Honolulu, Oahu, and at Midway Island. *C. magnificus* Reeve, recorded by Garrett (1878) from the Hawaiian Islands, is probably synonymous. A label, "*Conus magnificus* Reeve. Hawaiian Ids.," is present in the Garrett collection in the B. P. Bishop Museum, but no shell is present.

Conus cylindraceus Broderip and Sowerby

Several shells have been collected from dredged material at Midway Island. No specimens are known from the main Hawaiian Islands (Thaanum, *in litt.*).

Conus fabula Sowerby
(=**Conus scabriusculus** Dillwyn?)

The only known specimen, probably a subfossil, was collected at Makua, Oahu, by W. C. Ross.

Conus tenuistriatus Sowerby

Some authors have considered this species synonymous with (Tryon, 1884) or a variety of (Couturier, 1907; Dautzenberg, 1933) *Conus glans* Hwass *in* Bruguière. Several dead specimens have been dredged and a few have been collected on beaches in the Hawaiian Islands.

Conus tulipa Linné

Ostergaard (1928) reported collection of several fossil specimens, one of which is figured, of *Conus tulipa*. The identification of a fossil specimen, presumably collected by Ostergaard, in the Hawaii Marine Laboratory reference collection, has been verified by the writer as *C. tulipa*. Ostergaard (1928) referred to a "live immature specimen" of *C. tulipa* collected in Hawaii by C. H. Edmondson. It is possible that the specimen referred to was a *C. obscurus*, as several older specimens of that species were labeled *C. tulipa*. However, a single juvenile specimen of *C. tulipa* (No. 20), collected at Waikiki Reef, Oahu, is in the Hawaii Marine Laboratory reference collection. It is not known whether or not this specimen was alive when collected, but it is in fresh condition. A number of shell fragments of *C. tulipa* have also been collected on Hawaiian beaches.

UNVERIFIED AND INACCURATE RECORDS FROM THE HAWAIIAN ISLANDS

Conus arenatus Hwass *in* Bruguière

A single beach specimen, labeled "Hawaii. coll. W. H. Pease," is in the U. S. National Museum (No. 5038). No other specimens are known from the Hawaiian Islands, and the record may be in error as to locality.

Conus aristophanes Sowerby

This species, considered by Tomlin (1937) and others as synonymous with *C. coronatus* Gmelin, was described by Sowerby (1858) from the Philippine and Hawaiian islands. The latter locality is almost certainly in error.

Conus atramentosus Reeve

This is the type species of the genus *Lovellona* of Iredale (1917). Thiele (1931) considers *Lovellona* a section of the genus *Mitromorpha* A. Adams (1865) and places it in the subfamily Cytharinae of the family Conidae. Other authorities place *Mitromorpha* in the family Pleurotomidae (Simroth, 1896–1907).

Conus cancellatus Hwass *in* Bruguière

The type locality of this species is given in Bruguière (1792: 713) as "l'isle d'Owhyhée dans l'ocean pacifique." This is presumably an error, since no specimens from the Hawaiian Islands are known to the writer, although there is some resemblance to *C. acutangulus*. *C. cancellatus* is found in Japan.

Conus emaciatus Reeve

This species, considered by Tomlin (1937) and others as a juvenile of *C. virgo* Linné, was reported from the Hawaiian Islands by Sowerby (1858: pl. 12, sp. 191). This reference may be in error, since no specimens from Hawaii are known to the writer or D. Thaanum (*in litt.*).

Conus fusiformis Pease

Pease (1860) described this species from the Hawaiian Islands. It belongs to the genus *Mitromorpha*. (See under *C. atramentosus*.)

Conus miliaris Hwass *in* Bruguière

A specimen in the U. S. National Museum (No. 338481) now labeled "*Conus miliaris* Hwass" was collected by D. Thaanum at Keaukaha, near Hilo, Hawaii. Three live specimens were found in a sand pocket in the reef and apparently none have been collected since (Thaanum, *in litt.*). The specimens were first labeled by W. H. Dall as a variety of *C. abbreviatus*. The single discovery of three individuals in a small area suggests a small, isolated, aberrant population with possible fixation of atypical morphological character-

istics by genetic drift. The circumstances of collection thus lend support to Dall's conclusion that the specimens represent a variant of *C. abbreviatus*. However, the specimens agree quite completely on morphological grounds with typical *C. miliaris*, which is otherwise not known to occur in the Hawaiian Islands. It is possible that the specimens under consideration may have hatched elsewhere and have been carried ashore on Hawaii by currents during the pelagic larval stage. In either event, the population has apparently not become established in Hawaii.

The Museum National d'Histoire Naturelle, Paris, contains two additional specimens labeled "Kauai (Sandwich) Rémy 1857."

Conus parvus Pease

Pease (1868) having discovered that *C. fusiformis* was preoccupied, renamed that species *C. parvus*. See under *C. fusiformis*.

Conus virgo Linné

Although Garrett (1878) reported this species from the Hawaiian Islands, there is no specimen in the Garrett collection in the B. P. Bishop Museum, and no other records are known to the writer. Demond (1957) also lists this species from Hawaii.

SUMMARY

The gastropod genus *Conus* is represented by 33 species in the Hawaiian archipelago. This number comprises only species of which more than one individual has been collected alive in the area between Kure (Ocean) Island and the island of Hawaii. Synonymies, descriptions, type localities, and notes are given for each of these species.

One possibly additional valid species, a unique record of one species, seven species known in Hawaii only from the collection of dead specimens, and unverified and inaccurate records of nine species from the Hawaiian Islands, are cited.

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